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JOURNAL OF THE A·I·E·E·

NOVEMBER 1928

A E E I

PUBLISHED MONTHLY BY THE
AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS
33 WEST 39TH ST· NEW YORK CITY

MEETINGS

of the

American Institute of Electrical Engineers

WINTER CONVENTION, New York, N. Y., January 28-February 1, 1929

REGIONAL MEETING, Middle Eastern District No. 2, Cincinnati, Ohio, March 20-22, 1929

REGIONAL MEETING, South West District No. 7, Dallas, Texas, May 7-9, 1929

SUMMER CONVENTION, Swampscott, Mass., June 24-28, 1929

PACIFIC COAST CONVENTION, Los Angeles, Calif., September 3-6, 1929

MEETINGS OF OTHER SOCIETIES

New York Electrical Society, Engineering Societies Building, New York, N. Y., November 7, 1928

The American Society of Civil Engineers, Engineering Societies Building, New York, N. Y.

Regular Monthly Meeting, November 7, 1928
New York Sections Meeting, November 21, 1928
Annual Meeting, January 16-18, 1929 inclusive

The American Society of Mechanical Engineers, Engineering Societies Building, New York, N. Y.

Annual Meeting, December 3-7, 1928 inclusive

The American Institute of Mining and Metallurgical Engineers, Engineering Societies Building, New York, N. Y.

Annual Meeting, February 18-21, 1929 inclusive

JOURNAL

OF THE

American Institute of Electrical Engineers

PUBLISHED MONTHLY BY THE AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS
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(The Journal of the A. I. E. E. is indexed in Industrial Arts Index.)

Current Electrical Articles Published by Other Societies

Bulletin, National Electric Light Association, September 1928

Inspection and Testing of Cable,—Report of Committee on Underground Systems

Power Station Betterment,—Report of Committee on Prime Movers

Proceedings, Institute of Radio Engineers, October 1928

Electrical Prospecting, by J. J. Jakosky

Some Studies in Radio Broadcast Coverage in the Middle West, by C. M. Jansky, Jr.

A Study of Short-Time Multiple Signals, by J. B. Hoag

A New Method for Determining the Efficiency of Vacuum-Tube Circuits, by A. Crossly and R. M. Page

Some Principles of Grid-Leak Grid-Condenser Detection, by F. E. Terman

Simple Inductance Formulas for Radio Coils, by Harold A. Wheeler

A Gang Capacitor Testing Device, by Virgil M. Graham

Radiotelegraphic Center at Rome (San Paolo), by G. Pession and G. Montefinale

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DEVOTED TO THE ADVANCEMENT OF THE THEORY AND PRACTISE OF ELECTRICAL ENGINEERING AND THE ALLIED ARTS AND SCIENCES

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Vol. XLVII NOVEMBER, 1928 Number 11

A MESSAGE FROM THE PRESIDENT

A Few Thoughts Relating to Papers and Discussions

THE recently issued revision of "Suggestions to Authors" prepared by our Meetings and Papers Committee and the Publication Committee contains two new suggestions that deserve the earnest attention not only of prospective authors but also of program committees.

The first states that the introduction to papers *should show briefly the relation of the information in the paper to the advance of the art. By thus realizing and pointing out the justification for the paper, an author will usually approach his subject with a broader view and give to the paper a wider interest.*

It is mainly through technical papers that the principal object of the Institute is attained; namely, the advancement of the theory and practise of electrical engineering and of the allied arts and sciences. The second announced object, *the maintenance of a high professional standing among its members*, is certainly furthered by the advancement of engineers as useful and important members of society.

Recognition of the engineer's usefulness and importance can come only if he and his work are understood, and this is determined in large measure by the manner in which he describes his work and its results. In the final analysis the value of his message, be it the story of an experience or the exploiting of an idea or an ideal, depends on its ultimate relation to human welfare and human progress, both cultural and material.

If then the author will keep in mind the human purpose of the information he is presenting, he will be much more likely to win a large and attentive audience. The result should be a better understanding of the author and of his subject, and, incidentally, a more widespread and enhanced reputation for that engineer.

The second suggestion is found under Presentation of Papers. *Authors with limited speaking experience will doubtless profit by practising the presentation of their papers before delivery at a meeting. Possibly the criticism of friends will be helpful.*

It is a fact that engineers as a class do not enjoy a very high reputation as interesting public speakers. Would not improvement in this regard be a material help toward a better appreciation of engineers?

Discussion at meetings is also excellent practise, and program committees could well make special efforts to insure these contributions from the floor. Would it not stimulate efforts toward improvement if the sections adopted some scheme of giving recognition at each meeting to those two, three, or four who, in discussion, express themselves most clearly and forcefully?

While engineers generally have little ambition

"the applause of list'ning senates to command"

it seems strange that they do not more often reflect in their public speaking that abhorence of waste and desire for high efficiency for which the profession is noted.

R. F. Schuchardt

Some Leaders of the A. I. E. E.

William S. Murray, a manager of the Institute 1908-1912 and its vice president 1912-1914, is a native of Annapolis, Md. In 1895 he graduated from Lehigh University, with the degree of Electrical Engineer, and that year entered the employ of the Westinghouse Electric & Manufacturing Company at East Pittsburgh as an apprentice, receiving 12 cents an hour and the privilege of carrying his dinner pail.

With an ultimate objective of entering the consulting engineering field, during the following seven years Mr. Murray contacted with the manufacturing, testing, and engineering departments of that company, and in 1898, he was sent to Boston as its district engineer in charge of the New England territory, with headquarters at Boston. In 1902 he resigned from the Westinghouse Company, opening offices in Boston as a consulting engineer and practised there until 1905, when the New Haven Railroad called him as electrical engineer with headquarters at New Haven, to electrify their main lines out of New York City. This was the heaviest undertaking of its kind in the world, involving passenger, freight, and switching movements, costing approximately 25 millions of dollars, and occupying twelve years, during eight of which he was associated with his immediate superior officer, E. H. McHenry, then vice-president of engineering of the New Haven Railroad. For the last four years of that period, Mr. McHenry and Mr. Murray, each having resigned from the Railroad Company, operated under the firm name of McHenry & Murray, Mr. Murray accepting a new retainer with the New Haven Railroad as consulting engineer, reporting to the president, but with privileges to practise general electrification with Mr. McHenry.

During all of this period Mr. Murray was very active in Institute affairs, in addition to his managership and vice-presidency serving as chairman of a number of its committees, principally those in the field of electric traction. The TRANSACTIONS between 1905 and 1912 contain many of Mr. Murray's papers and discussions, of which perhaps the three most important are: (1) *The log of the New Haven electrification*; (2) *Electrification Analyzed and its Application to Freight and Passenger Operation*; and (3) *The Conditions Affecting the Success of Main Line Electrification.* This last paper was originally presented before the Franklin Institute and for it Mr. Murray received its Howard N. Potts Gold Medal award.

In 1917 Mr. Murray began to lay the foundation for his later investigations pertaining to the economic possibilities of regional interconnection of electric utility companies on the north Atlantic seaboard. This, in 1920, culminatied in his appointment by the Secretary of the Interior as Chairman of the Superpower Survey, the report on which was submitted to the government that same year. It delineated the proper coordination, by interconnection of existing and new electric power and load centers of the territory between Boston and Washington and involved a study of the electrification of some 96,000 diversified industries, and 36,000 mi. of heavy traction railroad within a zone in which there were then operating over 550 electric power stations. This report has been referred to as a classic in thee ngineering field—Mr. Hoover has mentionit as one in which "no hole has ever been kicked."

Having had opportunity to judge of Mr. Henry Flood, Jr.'s abilities during the period he had served as Engineer-Secretary of the Superpower Survey, (to which office Mr. Murray appointed him). Upon the completion of the Superpower Report, Mr. Murray invited him into partnership. The firm of Murray & Flood has enjoyed an unusually fine clientele from many of the electric utility companies in this country from coast to coast.

Mr. Murray believes in American initiative and advocates private, as against government, ownership of the American utilities. In his book "Superpower—Its Genesis and Future"—are statements that leave no room for doubt as to his position in this matter.

The Saluda River hydroelectric project, which is now being constructed by the Lexington Water Power Company of Columbia, South Carolina, owes its existence to Mr. Murray. On a U. S. G. S. topographical map, he discovered the possibility of this development and confirmed it by a personal visit and survey of the territory. To control the situation, it became necessary for Mr. Murray to invest a very large part of his own savings in a charter, and to secure some of the lands necessary to the development. It was a challenge to his engineering and economic knowledge which he lost no time in accepting. Several avenues were open to finance the $20,000,000 development. With the General Gas & Electric Corporation elected for this purpose, the project is now one-third completed. Perhaps one of the largest individual contracts for power, (if not the largest), was consummated by Mr. Murray for the annual delivery of 150,000,000 kw-hr. to the Carolina Power & Light Company from the Saluda development; delivery of power will begin September 1, 1930, and Murray & Flood are the engineers for the construction of the largest dam in the world across the Saluda River; a dam over 8000 ft. long, 208 ft. high and to contain 11 million cu. yds. By it will be created a lake 35 mi. in length with a width at one place of 14 mi.

In honor of the discovery of this great power development, which will include an aggregate capacity of 300,000 hp., the Legislature of South Carolina by a unanimous vote of its House and Senate, has named the lake "Lake Murray," forwarding its Concurrent Resolution to Mr. Murray under the seal of the state.

Abridgment of

Residual Voltages and Currents in Power Systems

BY L. J. CORBETT[1]
Member, A. I. E. E.

Synopsis.—In the problem of inductive coordination of power and communication systems, residual voltages and currents in the power lines are an important element; yet it is apparent that they are not, in general, well understood. Studies have been made, and others are under way by well-equipped organizations, which will add much to the data concerning them. In this paper the general principles which apply are reviewed briefly and applied to typical power circuits and networks, and oscillograms are shown which verify the theory presented.

* * * * *

Balanced and Residual Voltages and Currents

In the ideal three-phase circuit, the vector sum of the voltages to ground of the phase wires is zero, and the vector sum of the currents in the three wires is also zero. In the practical three-phase circuit such is not the case. The vector sum of the voltages to ground of the phase wires is never quite zero, and the vector sum of the currents in the three wires is not zero. In inductive coordination studies, it is customary to divide the voltages to ground and the currents into "balanced" and "residual" components.

The balanced voltages are those components of voltage to ground which are equal in value and so related in phase that their vector sum is zero.

The residual voltage is the vector sum of the voltages to ground of the phase wires. It is equivalent to a single-phase voltage impressed between the three wires in multiple and ground.

The balanced currents are those components of the currents in the wires whose vector sum is zero. They are confined to the wires of the circuit and their algebraic sum, from instant to instant, is also zero.

The residual current is the vector sum of the currents in the three phase wires. It is equivalent to a single-phase current in a circuit consisting of the three wires in multiple as one conductor and ground as the other.

In recent terminology the balanced components are those of positive and of reverse phase sequence, the residual being a zero-phase sequence component.

The effects of balanced voltages and currents can be neutralized to a large extent by the use of suitably coordinated transpositions in the power and telephone circuits. The effects of residual voltages and currents are cumulative along an exposure, bringing the potential of the telephone line and equipment to a relatively high value above ground. Induction from these components obviously is not affected by transpositions in the power circuit.

1. Assistant Engineer, Pacific Gas and Electric Company, San Francisco, Calif.

Presented at the Pacific Coast Convention of the A. I. E. E., Spokane, Wash., Aug. 28-30, 1928. Complete copies upon request.

Generator Wave Form

The type of wave of voltage striven for in the design of a-c. generators is the pure sine wave. This in impossible of exact attainment, but a very close approximation is reached in modern designs. In the Standardization Rules of the Institute a limit is set for the deviation factor, a measure of the deviation of the actual open-circuit terminal voltage wave of a synchronous machine from a pure sine wave.

Actually certain harmonics are present in the generator wave in varying amounts. If the positive lobe of the wave is identical with the negative lobe, only odd harmonics are present. The tendency is for the higher harmonics to be damped out in the impedance or magnified slightly in the capacitance of the circuit to which the generator is connected. At times certain harmonics are carried through one or two transformations and can be detected from their inductive effects on paralleling communication circuits.

Transformer Exciting Current

The chief cause of higher harmonics in a power system is the exciting current of the transformers. Even if the generator wave is a pure sine wave of voltage, the exciting current demanded by the transformers will contain higher harmonics superposed on the fundamental wave if the circuit will permit their flow. If it will not, the deficiency shows up as higher harmonics in the voltage wave.

The exciting current of the single-phase transformer contains a pronounced third harmonic, an appreciable fifth, and higher harmonics in varying amounts. Working the iron at high saturation increases the magnitude of the harmonics, also bringing out some of the higher ones which are not noticeable at low densities.

Tramsformer Connections

When transformers are connected in banks on a three-phase system, certain connections permit the flow of harmonic currents, and others do not. It is not intended here to repeat analyses of a large number of possible combinations, but to emphasize the relations existing on a few of the types commonly used. An

elemental system supplied from one generator is shown in Fig. 4.

Generator

Present practise favors the Y connection for three-phase generators, with neutral grounded either solidly or through a resistance. This limits the insulation strain on the windings definitely to the Y voltage. It is somewhat easier to obtain a good wave form with this than with the delta connection.

Step-Up Transformers

Practise also favors the delta connection for the primary of the step-up transformer bank. In this connection, a sine wave of voltage between conductors will result in a peaked wave of magnetizing current, the necessary third-harmonic currents being in phase in each transformer, and thus circling around in the closed delta with very low impedance. The secondary voltage will then be free of third-harmonic components.

If harmonics other than the fundamental are present in the wave of applied voltage, the same considerations as noted regarding the third-harmonic current apply to the third multiples of the other harmonics; such as the 9th, 15th, 21st, 27th, 33rd, etc., which will be represented in the delta current, as these will be required in the magnetizing current in order that the 3rd, 5th, 7th, 9th, 11th, etc., components of the primary voltage may faithfully be passed on to the secondary side.

The secondary or line side of the step-up transformer bank is usually connected Y, with grounded neutral. As in the case of the generator, this adds to safety and reliability of operation by limiting the voltage from line to ground definitely to the Y voltage. Thus far, on our typical system, if we started with a good one at the generator, we have a good wave form of voltage on the line.

Step-Down Transformers

Again practise favors the Y-grounded connection for the line side of the step-down bank,—in this case the primary side. With practically a sine wave of voltage applied, these transformers demand the harmonics required in the magnetizing current in order to produce the same type of voltage wave. Each transformer therefore will draw from the line, if the connections permit, current of 3rd, 5th, 7th, 9th, 11th, etc., harmonics of the fundamental frequency.

Taking the 3rd harmonic as of major importance in this analysis, it will be recalled that in a three-phase system, the third-harmonic components, either of voltage or current, will be three times 120, or 360, deg. apart; in other words, in phase with each other. With the ground connection on the neutrals of both step-down and step-up banks, a path is provided for these in-phase components of the magnetizing current. The third-harmonic currents demanded in each leg of the step-down bank cannot pass out to the line through the other two legs of the Y, but they can pass through the neutral connection and ground to the neutral of the step-up bank, and through the Y-connected secondary windings of that bank to the line, thus finding a closed path. The delta-connected primary windings of the step-up bank allow rather free circulation of any third-harmonic currents necessary to offset those demanded by the step-down bank. The "triples" thus find in that bank a low-impedance portion of their path, the rest of it consisting of the loop formed by the three conductors in parallel and the ground, and the bank demanding them.

The third-harmonic currents thus form the chief portion of the residual current. Other important components are the 9th, 15th, 21st, etc., harmonics, if the 3rd, 5th, and 7th harmonics were present in the voltage wave. The term "triples" applies to all such components

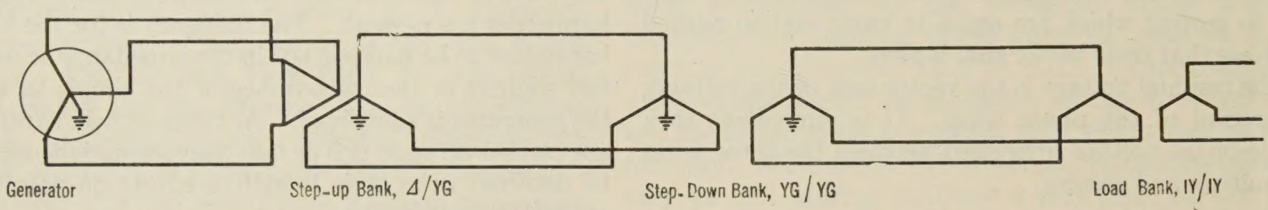

Fig. 4—System Supplied from One Generator

Those harmonics of exciting current whose designating number is not divisible by 3, such as the 5th, 7th, 11th, 13th, etc., are supplied over the line, and, like the fundamental, the resultant for each is zero. They, with the fundamental, form the balanced components of the current.

Practically, the voltage wave is not of perfect sine form; transformers are not always exactly alike; load is not always balanced; unequal leakage from the conductors to ground takes place; the capacitances from conductors to ground are not always equal. All of these factors contribute to add small amounts of fundamental and other odd harmonics to the residual current, but those mentioned, the 3rd, 9th, 15th, etc., predominate.

Load Bank

The load bank in Fig. 4 is represented as connected Y-Y, with isolated neutral. In this type of connection, the triple-harmonic currents demanded by the exciting current of the transformers cannot flow, as no path is provided for them. The deficiency of third harmonic in the magnetizing current appears as a third harmonic in the secondary voltage and distortion of the applied voltage wave. The same is true of the other harmonics which seek the neutral path,—the 9th, 15th, 21st, etc. As in the case of the currents, these harmonics combine

into a residual voltage by which the isolated neutral differs from ground potential. This difference is superposed upon the various phase-wire voltages from ground, and there results a residual electrostatic field in the medium surrounding the conductor which varies with the frequency and resultant magnitude of these harmonics.

As in the case of the currents, those harmonics of voltage whose designating numbers are not divisible by three,—such as the 5th, 7th, 11th, 13th, etc., appear on the different conductors, but their resultants are each zero.

If the load bank is connected Y-Y with the primary neutral grounded, the third-harmonic currents required for magnetization can come only from the step-down bank, through the conductors and ground return. In order to supply them, the step-down bank must draw upon the step-up bank with its delta-connected primary. Thus the load bank increases the residual current in the line back to the source which can furnish them.

If the secondary of the load bank is connected delta, and the ground on the primary neutral is removed, no third-harmonic currents can flow in the primary, and the secondary voltage wave and the primary wave of back e. m. f. tend to become distorted. However, at the slightest appearance of a third-harmonic in the delta voltage, a third-harmonic current flows in the closed delta and supplies the deficiency in magnetization, so that the voltage waves remain smooth except for the small amount of triple-harmonic necessary to overcome the triple-harmonic impedance.

If the primary neutral is grounded, the secondary being delta-connected, nearly all the third-harmonic magnetizing current will be supplied by the secondary delta. Some, however, will be supplied to the primary over the line from the source through the step-down bank. The relative amount of third-harmonic current supplied by the secondary delta and the line will depend upon their relative impedances. The delta secondary path will have, in general, a very low impedance compared to the line path, so that there will be very little residual current in, or voltage on, the line between the load bank and the step-down bank.

Tertiary Windings

If separate windings are added to the transformers of the step-down bank, and connected delta, most of the triple-harmonic currents required for the excitation of that bank and of the load bank will be supplied in the delta circulating current, so that the line back to the step-up bank will be comparatively free of residual current. The division will depend upon the relative impedance. If the delta is of large kv-a. capacity with low impedance it will be more effective in this regard than if of small kv-a. capacity with high impedance.

Power Networks

The usual power system is not so simple as the elemental one used for analysis. Most systems have more than one power station with more than one generator and transformer bank at each feeding the system at different points and into multiple lines. When some of the transformers are connected Y-grounded on both sides, some with tertiary-delta windings, some Y-delta, some delta-delta or delta-Y, it is rather difficult to trace out fully the course of the residual currents, which is further complicated by variations due to system changes.

However, by analyzing the conditions from the fundamental principles just treated, at least the general features of any problem can be determined, and reasons deduced for any particular conditions encountered.

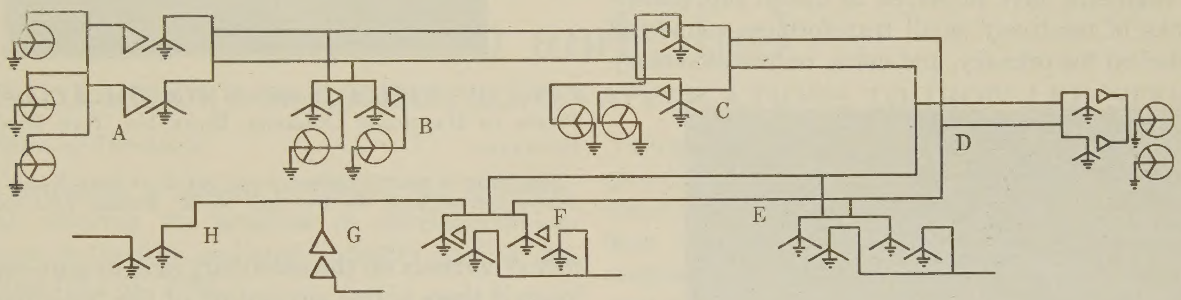

Fig. 9—Typical System Network

In Fig. 9 a more complex condition is presented. *A* and *B* are power plants not far apart feeding into twin transmission lines. At *C* is a station with step-down auto-transformer banks with delta-tertiary windings which are connected to synchronous condensers. Another power plant feeds in at *D*, and at *E*, *F*, *G*, and *H* are step-down stations serving communities and industries.

The delta-Y-connected plants deliver a good wave form of voltage to the line. The Y-connected auto-transformers at *C*, if the tertiary delta is of sufficiently low impedance, will furnish practically all the triple harmonics needed by those banks whether the condensers are on or not. The Y-Y grounded banks at *E* will require triples for their magnetizing current. They will draw them from the banks with deltas in them, at *D* and *C*, the relative amounts depending upon the impedance of the paths to these sources. The banks at *F* with delta tertiaries will supply practically all their own triples unless the tertiary impedance is high, in which case, part of them will be furnished from *D* and *C* also.

The bank at *G*, being delta-connected on the primary, will not affect the situation regarding triples at all. The bank at *H*, connected Y-Y with grounded neutrals,

will require triple harmonics of current. The bank at G cannot supply them; so they must come from F, and possibly some must come from D and C.

If a power network is well supplied with banks having delta windings, the residual currents are reduced to low values. The most effective means for their suppression is to have the delta in the bank itself, either

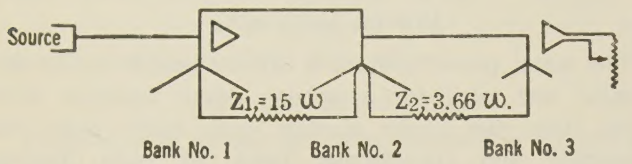

FIG. 15—CONNECTIONS FOR REGULATION OF RESIDUAL CURRENTS

as a delta connection on primary or secondary, or as a tertiary winding, if it is a Y-Y bank. At a station where there is a number of banks, the use of such windings in one or two of the banks will serve for all practical purposes,—while the banks so equipped are in service.

SUPPLEMENTARY Y-DELTA BANKS FOR SUPPRESSING RESIDUALS

Some engineers have preferred to install supplementary banks of relatively small transformers connected Y grounded on the primary, and delta, on the secondary

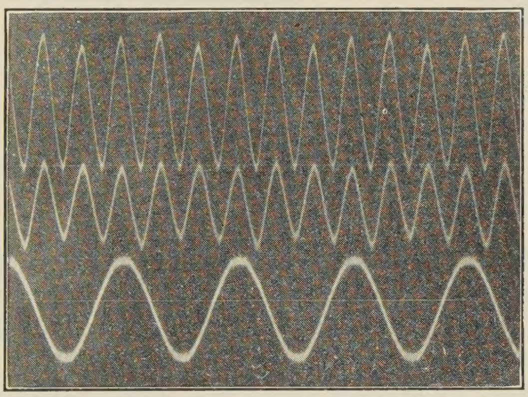

FIG. 16—NEUTRAL CURRENTS WITH DELTA OPEN

Top curve is neutral current, bank No. 2 to bank No. 3. Middle, neutral current, bank No. 1 to bank No. 2. Bottom, line voltage, 220 volts

side, where suppression of residual currents and voltages was required. Such a bank will do its share of the task of furnishing triple-harmonic components of magnetizing current, its effectiveness being in inverse ratio to its impedance compared to other available paths. In the individual case, the effectiveness desired and the comparative cost of the separate bank and the addition of tertiary windings on the main bank, including installation, will govern.

Such a bank is most effective if connected to the same line as the main bank, or banks, rather than on the secondary lines. In the latter case, the additional impedance of the main bank, or banks, is added in the path of the necessary compensating harmonic currents.

LABORATORY TESTS

In order to check some of the features outlined regarding banks of single-phase transformers, an interesting series of experiments was conducted in the laboratory of the Pacific Gas and Electric Company at Emeryville, Calif., with three banks of 1-kw. transformers, using the 110-volt windings as primary and secondary and taping up the 2300-volt terminals, except that in some of the experiments the 2300-volt windings of one bank were used as a closed delta. By confining attention to the exciting currents the relative values of the harmonic currents were appreciably large. A number of conclusions was determined by the tests, which substantiated the theory presented.

A Y-Y grounded bank will not send out triple-harmonic currents on the secondary side to pure-resistance loads if there is free circulation of the triple harmonics required on the primary side for excitation. If the latter are suppressed, causing triple harmonics of voltage on the secondary side, there will be triple-frequency components in the load current.

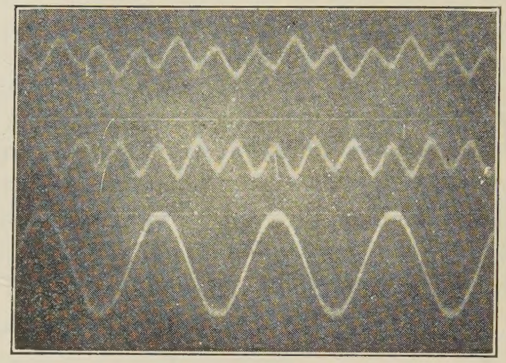

FIG. 18—NEUTRAL CURRENTS WITH DELTA CLOSED SOLID. PHASE OF HARMONIC CURRENT, BANK NO. 2 TO BANK NO. 3 REVERSED

Top curve is neutral current, bank No. 2 to bank No. 3. Middle. Neutral current, bank No. 1 to bank No. 2. Bottom: Line voltage, 220 volts

Another matter determined was the action of a delta

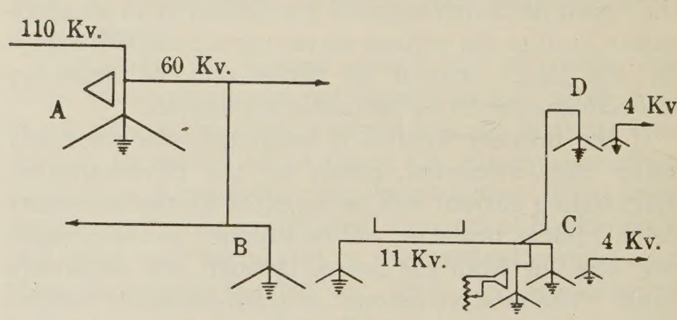

FIG. 19—RESIDUAL CURRENTS SUPPRESSED BY SUPPLEMENTARY BANK

secondary (or tertiary) winding, in supplying a part only, all required, or an excess of triple-harmonic current over that required in the same bank. The connections for this test were as shown in Fig. 15, the transformers in the first two banks in this case being connected as auto-transformers, the delta in the first bank consisting of the 2300-volt windings.

With the delta of bank No. 3 completely open, the

oscillograph was set so that one wave of each of the neutral currents and the 60-cycle line voltage were in phase as shown in Fig. 16.

By adjusting the resistance in the delta it was possible to reduce the neutral current to practically a fundamental-frequency wave.

When the delta was closed completely, it not only supplied all the triple-harmonic current required by its own bank, but aided in filling the demands of bank No. 2. This may be noted from Fig. 18, where it will be seen that the residual current has completely reversed in phase between the second and third banks.

FIELD TESTS

A very similar arrangement was set up in the field at a substation connected to a line which had given trouble from residual currents. The conditions were as indicated in Fig. 19. An auto-transformer bank at *A* contained a delta, but at *B*, the voltage was stepped down from 60,000 to 11,000 volts through a Y-Y bank with neutrals grounded. The 11,000-volt line supplies two stations also equipped with Y-Y banks transforming from 11,000 to 4000 volts. A parallel existed between *B* and *C* on the 11,000-volt line.

A supplementary bank of about 25 per cent of the capacity of those at *C* or *D* was installed at *C*, connected Y-grounded on the primary, and delta on the secondary side, with an adjustable resistance across one corner of the delta. With the delta open the triple-harmonic currents were supplied from *A* through bank *B* for the banks at *C* and *D*. It was possible to vary the resistance till the residual current in the line was approximately all fundamental, but due to system variations and lack of facilities to observe and make the exposure at the same time, no oscillogram of this condition was obtained. A complete reversal was noted, indicating that when the delta was closed, the supplementary bank, supplied the triple-harmonic currents required by its own primary windings, by the large bank at *C*, by the bank at *D*, and a portion of those required by the bank at *B*. This corresponds to the results obtained in the laboratory on the somewhat similar set-up shown in Fig. 15, in which the conditions were more easily controlled.

Iron and Steel

ANNUAL REPORT OF COMMITTEE ON APPLICATIONS TO IRON AND STEEL*

To the Board of Directors:

Your committee is pleased to present the following statement covering the progress of development in applications in the iron and steel industry during the year ending July 31, 1928.

Constantly during this period, the iron and steel industry has added to its general electrical equipment. These general additions have been towards the modernizing of existing installations quite as much as anything, and all effort is directed steadily towards reduction in production costs by addition of improved machinery.

The tendency to increase blast furnace equipment is not present, and this may be said to be true generally of the fundamental processes of smelting iron ore, in coverting iron into steel or in rolling the steel into the primary shapes. Such electrical additions as have been made in the foregoing are in the nature of changes of older equipment to modern.

The principal interest during the current term has been in the finished product mills, which we shall term the secondary mills.

Predominant in this regard are installations in strip mills and in cold rolling, these electrical installations being modern and recording definite advance in the production of hot strip steel and in cold-rolled strip.

Close regulation of the mill drive is required and to give this, motors and control have been developed and installed. Micrometric adjustment of the rolls has been obtained through motors and control specially designed for the purpose. The reeling of the strip steel has been accomplished automatically by mechanical tools, electrically driven and controlled. This accomplishment marks a definite advance in the production of perfect strip steel.

Steady improvement in detail of motors and control for such service is shown in the apparatus installed, and this is marked rather than any positively new product of our industry.

Throughout the term, your committee has kept in touch with the proceedings and personnel of the Association of Iron and Steel Electrical Engineers. It has been the committee's purpose to help the Association as it might, and its Proceedings are referred again to the Institute as the most complete record available of electrical developments in the iron and steel industry.

In conclusion, your committee commends the plan of keeping continually in touch with the Association of Iron and Steel Electrical Engineers, giving it service wherever possible and bringing to the Institute its reports and findings, with suitable recognition. Your committee just concluding its services takes this means of acknowledging and expressing appreciation of the assistance rendered by these reports for the current term, as well as by the constant contact with representatives of the Association.

A. G. PIERCE, *Chairman.*

*APPLICATIONS TO IRON AND STEEL PRODUCTION:

A. G. Pierce, Chairman,

A. C. Bunker,	S. L. Henderson,	F. O. Schnure,
F. B. Crosby,	O. Needham,	J. W. Speer,
A. C. Cummings,	A. G. Place,	G. E. Stoltz,
M. M. Fowler,		T. S. Towle,

Presented at the Summer Convention of the A. I. E. E., Denver, Colo., June 25-29, 1928. Printed complete herein.

Abridgment of

Arrangements of Feeders and Equipment for Electrified Railways

BY R. B. MORTON[1]

Fellow, A. I. E. E.

Synopsis.—This paper outlines the general requirements governing arrangements of distribution system and substation equipment for electrified railways. By way of illustration, it presents a general description of the conversion and distribution facilities as recently installed in the electrification of the New York Connecting Railroad-Long Island Railroad to Bay Ridge, and in the electrification, now nearing completion, of the Philadelphia-Wilmington and West Chester lines of the Pennsylvania Railroad.

Introduction

SUBSTATION equipment necessarily includes conversion apparatus required to translate the power received over transmission lines into suitable form for delivery to the contact system. Such apparatus is usually provided in units so proportioned as to load capacity that the outage of any one unit will not place limitations to the movement of traffic.

Switching equipment must be provided which, in the event of short circuits, will quickly and automatically interrupt the supply of power, and so confine the effect of such interruption as to cause the least practicable disturbance to movement of traffic.

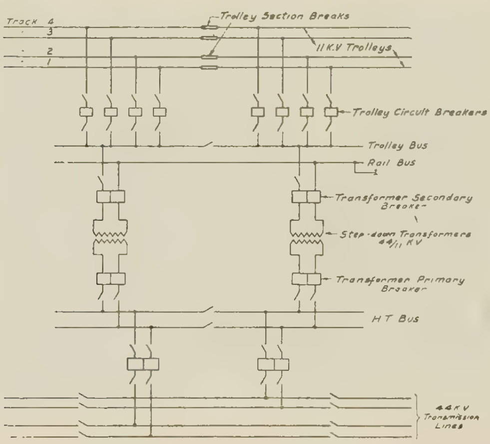

Fig. 1—Schematic Diagram of Typical Substation

Pennsylvania Railroad—Paoli-Chestnut Hill Electrfication

The several examples of railway electrification, to which reference is made in this paper, are of a type utilizing the single-phase a-c. system of traction.

There may be said to be at least four rather distinct methods of arranging the switching equipment in substations, namely:

1. An arrangement which provides for switching, under load, the transmission circuits, high and low sides of transformers, and trolley feeders, as in the case of the original Paoli-Chestnut Hill electrification of the Pennsylvania Railroad (Fig. 1).

2. An arrangement which provides for switching on the high tension side only for controlling both transmission and trolley circuits, as in the case of the Virginian Railway (Fig. 2).

3. An arrangement which provides for switching, under load, the transmission, and trolley feeder circuits, but not the transformers, as in the cases of the original electrification of the Elkhorn Grade on the Norfolk & Western Railway (Fig. 3) and the New York Connecting-Long Island Railroads (Fig. 5).

4. An arrangement which provides for switching under load, on the low-tension side only, for controlling both high-tension and low-tension circuits, the transformers being switched and regarded as a part of the transmission system, as in the case of the recent Pennsylvania Railroad Suburban and Through Electrification (Fig. 7).

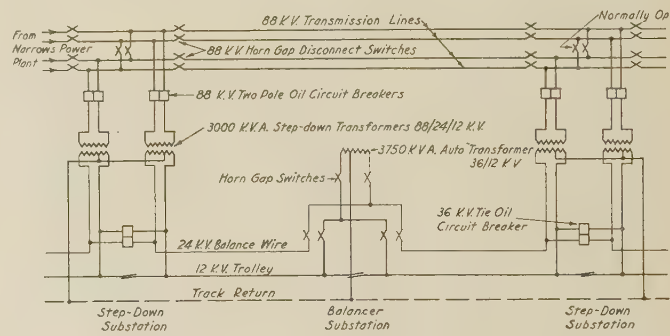

Fig. 2—Diagram of Typical Step-Down and Balancer Substations

Virginian Railway Electrification

An example of simplified substation switching equipment will be noted in the electrification of the Virginian Railway. This system has been described in detail in a paper[2] recently presented before the American Society of Civil Engineers. In a typical substation serving the single-track portion of this railroad, there are provided three oil circuit breakers. Two of these are high-tension breakers, interposed between the transmission lines and the step-down transformers, while

1. Project Engineer, Gibbs & Hill, New York, N. Y.

Presented at the Summer Convention of the A. I. E. E., Denver, Colo., June 25-29, 1928. Complete copies upon request.

2. *Proceedings*, A. S. C. E., Jan. 1928, p. 3, by George Gibbs.

the third is a low-tension breaker, serving to equalize the load on the transformer secondaries, or, in the event of one of the transformers or one of the transmission lines being out of service, serving to feed both trolley

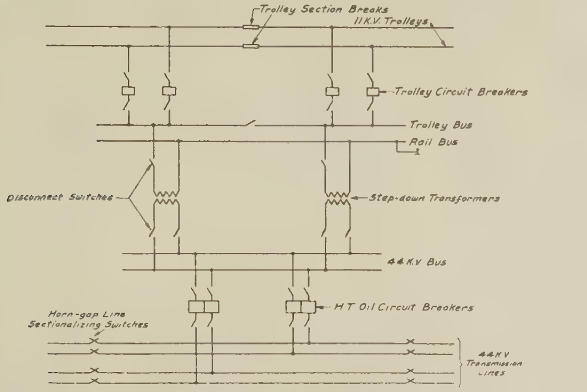

FIG. 3—SCHEMATIC DIAGRAM—MAYBEURY SUBSTATION

Norfolk & Western Railway—Elkhorn Grade Electrification

sections from one transformer. Fig. 2 shows diagrammatically the arrangement of power connections.

The electrification of the New York Connecting Railroad–Long Island Railroad to Bay Ridge, com-

FIG. 4—MAP OF ELECTRIFIED SYSTEM

New York Connecting Railroad—Long Island Railroad—Bay Ridge Improvement

pleted and placed in operation during the summer of 1927, may be taken as illustrative in the arrangement of its feeders and substation equipment. A general description of these features may be of interest.

NEW YORK CONNECTING RAILROAD–LONG ISLAND RAILROAD TO BAY RIDGE

This electrification covers a route 20 mi. in length, extending from a freight terminal yard at Bay Ridge, Brooklyn, to a point of connection with the Harlem River Division of the New York, New Haven & Hartford Railroad at Port Morris, Borough of the Bronx (Fig. 4).

With the exception of a few passenger trains daily over the Hell Gate Bridge route, which service was inaugurated in 1917, traffic consists of through freight trains operated by the New Haven Railroad between

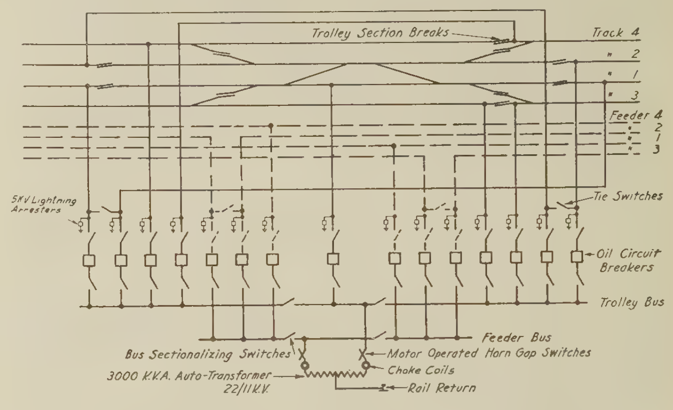

FIG. 5—SCHEMATIC DIAGRAM—"NO" SUBSTATION

New York Connecting Railroad—Long Island Railroad—Bay Ridge Improvement

Bay Ridge and Port Morris, way freight and through freights operated by the Long Island Railroad between Bay Ridge and Fresh Pond Junction, and yard switching at Bay Ridge and New Lots.

Power Supply. The system of electrification is

FIG. 6—MAP OF PHILADELPHIA SUBURBAN ELECTRIFICATION, PENNSYLVANIA RAILROAD

fundamentally an extension of the New Haven electrification, with 11,000-volt trolleys and 11,000-volt feeders of opposite polarity, forming a 22,000-volt, three-wire system. At present, power for operation is received from the New Haven system, which in turn is supplied principally from its own generating station at Cos Cob, approximately 42 mi. from Bay Ridge,

and also in part from purchased power delivered to the New Haven at West Farms, Devon, and New Haven.

Substations. A total of six auto-transformer stations

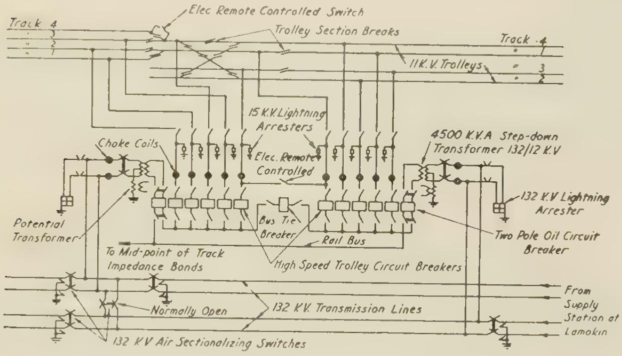

FIG. 7—SCHEMATIC DIAGRAM—BELLEVUE SUBSTATION
Pennsylvania Railroad—Philadelphia Suburban Electrification

have been provided, separated by an average interval of 3.8 mi. The locations of these substations, number and size of transformers, and number of trolley and feeder circuit breakers in each are as follows:

Location	Auto-transformers	Trolley breakers	Feeder breakers
Bungay Street	1—3000 kv-a.	5	6
Bowery Bay	1—3000 kv-a.	9	6
Fresh Pond	1—3000 kv-a.	9	6
New Lots ("NO")	1—3000 kv-a.	9	6
Manhattan Beach Jct.	1—3000 kv-a.	7	8
Fourth Ave., Bay Ridge	2—3000 kv-a.	6	4

The transformers are of the outdoor type, self-cooling, and have a turn ratio of 22,000:11,000 volts. The rating as an auto-transformer corresponds to a coil rating of 1500 kv-a. for each half of its winding. The transformers are capable of carrying 150 per cent of rated load for one hour, following continuous rated load, and this followed by 300 per cent of rated load for five minutes.

The transformers are connected to trolley and feeder buses through two-pole, 22,000-volt motor operated horn-gap switches.

A schematic diagram of one of the substations, indicating the arrangement of connections of trolleys and feeders, is shown in Fig. 5. It will be noted that at this substation, two of the four feeders are tapped and the other two are looped. At the next adjacent substations, the order is reversed.

All auto-transformer substations are unattended. The circuit breakers and motor-operated horn-gap switches in each substation are controlled from a panel mounted in a signal interlocking tower nearest to that station. In the case of Bowery Bay Substation, it was necessary to utilize a system of superv sory control from Bungay Street tower, a distance of three and a half miles.

Distribution System. The feeder side of the three-wire distribution system comprises four 4/0 copper conductors extending the entire length of the line, as far as Bay Ridge substation. These feeders are carried on pin type insulators of 45,000-volt service rating. Between Fresh Pond and East New York is a four-arch tunnel, 3500 ft. long, in the outside walls of which are banks of cable ducts. Through these ducts four paper-insulated, lead-sheathed cables of 350,000 cir. mil, are used.

The trolley system for all main running tracks comprises a 4/0 bronze contact wire, 65 per cent conductivity, reinforced by a 4/0 copper auxiliary, supported by a 19-strand messenger of 5/8-in. diameter, of high-strength bronze. In yard construction the copper auxiliary is omitted.

Track Return. All rail joints on main tracks are single bonded with a No. 1 bond, gas welded to the head of the rail. In yard tracks one rail only is bonded.

The three-wire system of distribution was selected for the New York Connecting Railroad–Long Island Railroad, Bay Ridge line, mainly for the reason that this electrification is fundamentally an extension of the existing electrification of the New York, New Haven & Hartford Railroad. The distances from the sources of power are considerable, but are within the range of economical transmission for the voltage employed.

PHILADELPHIA SUBURBAN ELECTRIFICATION OF THE PENNSYLVANIA RAILROAD

The electrification of Maryland Division main line from Philadelphia to Wilmington, Del., a distance of about 27 mi., and of the Wawa Branch to West Chester, a distance of about 26 mi., is now nearing completion (Fig. 6). Approximately 105 mi. of electrified track are involved in the main line work, and approximately 50 mi. in the Branch.

Substations have initially been equipped for supplying power for the operation of multiple unit trains only, but the Wilmington line has been designed to later form a part of through electrification between New York and Washington, with locomotive operation of main line freight and passenger services.

Power Supply. Power for the electrification is supplied by the Philadelphia Electric Company at 13,200 volts, 25 cycles, single-phase, delivered on the bus bars of the Railroad Company's step-up station at Lamokin Street, Chester. Three self-cooled single-phase transformers of 15,000-kv-a. continuous rating are provided for stepping up this power to a transmission potential of 132,000 volts. This transmission potential was selected by reason of the large amounts of power which will be required for the ultimate through electrification, and the considerable distances to be covered.

Initially, two transmission circuits of 4/0 copper are provided, which are supported on the catenary structures. Ultimately it is planned that the number of transmission circuits along the main line may be increased to four.

Substations. A total of nine substations is provided in which the power is stepped down to a trolley potential of about 11,000 volts. The locations of these stations, number and size of step-down transformers, and the number of trolley circuit breakers in each, are as follows:

Location	Transformers	Trolley breakers
Wilmington	2—4500 kv-a.	4
Bellevue	2—4500 kv-a.	10
Lamokin	2—4500 kv-a.	10
Glenolden	2—4500 kv-a.	8
Arsenal Bridge	2—4500 kv-a.	9
Morton	2—4500 kv-a.	4
Lenni	2—4500 kv-a.	3
Cheyney	1—4500 kv-a.	1
West Chester	2—4500 kv-a.	1

The average interval between substations is 6.4 mi.

It is planned that the number of step-down transformers in each of the substations serving the main line may ultimately be increased to four.

The transformers are self-cooling and are capable of carrying continuous rated load, followed by 150 per cent of rated load for two hours, followed by 300 per cent of rated load for five minutes.

A schematic diagram of one of the substations, indicating the arrangement of connections, is shown on Fig. 7.

A feature of these substations, as well as of the step-up substation, is the absence of oil circuit breakers in the high-tension side.

In the step-up substation oil circuit breakers are provided in the low-tension side of the transformers, giving automatic protection in the event of transmission line fault. The transformers are connected on the high-tension side to outgoing transmission lines through two-pole 132-kv. air sectionalizing switches, remote electrically controlled, which are not to be opened under load but are capable of interrupting transformer exciting current.

In a similar manner, the transformers in each of the step-down substations are connected to the high-tension lines through air sectionalizing switches, and the low-tension side of each is connected to trolley and rail buses through a two-pole oil circuit breaker, arranged for automatic tripping on reverse power, on unbalanced voltage on the high-tension side, or by differential protection against failure on the trolley bus or within the transformer. A fault on any part of a 132-kv. transmission circuit will trip out of service one transformer in the step-up station and one transformer in each step-down station which is served by the transmission line on which the fault occurs. Such an outage should not affect train operation, as sufficient transformer capacity remains in each substation to handle maximum expected loads. If the transmission line fault is to ground only and does not involve the opposite conductor, the flow of current through the earth, back to the step-up station is limited to about 200 amperes by a neutral resistance connected to the mid-point of each step-up transformer.

Trolleys are sectionalized at each substation and each trolley section is normally fed from each end. Trolley circuit breakers are designed to open under short circuit within an interval of time not exceeding 1/25 sec. The rupturing capacity of these circuit breakers is 50,000 amperes. This high value of rupturing capacity was required with a view to ultimate conditions as to transformer capacity at step-up and step-down substations. This installation represents the first use on any extensive scale of quick opening circuit breakers in a-c. railway electrification, and it is expected that inductive disturbances and damage to overhead wires and insulators resulting from trolley short circuits will be minimized by the quick acting feature.

At each substation there is provided a small building to house a control storage battery and charging equipment, protective relays and oil conditioning apparatus. All other equipment is of outdoor type.

Substations are unattended, and are controlled from a panel containing control switches and indicating lamps placed in signal interlocking towers or other points continuously attended. Certain substations on the West Chester branch are so remote from a continuously attended tower that it was necessary to provide supervisory control for these substations, utilizing wire circuits in an aerial cable along the right-of-way.

Contact System. The contact system for all main running tracks comprises a 4/0 bronze contact wire, 40 per cent conductivity referred to copper, reinforced by a 4/0 copper auxiliary, supported by a 19-strand bronze messenger of ⅝-in. diameter, of high strength and relatively low conductivity. In yard construction the copper auxiliary is omitted.

Track Return. All rail joints on main track are double bonded, not for conductivity but to minimize signal failure due to broken bonds. A major portion of the trackage is bonded with No. 1 bonds, gas welded to the head of the rail, and on the remainder of the work No. 1/0 bonds with expanded pin terminals are used, installed where possible under the joint plates.

The type of system of transmission, conversion and distribution adopted for the Philadelphia-Wilmington electrification gives a high degree of selectivity in the automatic tripping of circuit breakers in the event of short circuits, and is adaptable to future extensions over considerable distances and to such increase in installed capacity as will be required for the future operation of through freight and passenger traffic. The West Chester line was equipped in a manner similar to the Philadelphia-Wilmington line, partly for the sake of uniformity of apparatus, and partly because in connection with future extensions of the electrification on the main line to the west and elsewhere, the 132-kv. transmission lines will ultimately be used as a part of a transmission network.

Abridgment of

Electric Conduction in Hard Rubber,

Pyrex, Fused and Crystalline Quartz

BY HUBERT H. RACE[1]

Associate, A. I. E. E.

Synopsis.—*The study of physical and electrical characteristics of insulating materials is of growing importance to the electrical industry because of the ever-increasing potentials employed in electric enerating and distributing equipment. The particular problem presented in this paper is related to engineering practise because polarization and conduction both result in the conversion of electric energy into heat. This produces increased local and general heating, which may be contributing causes to the progressive deterioration and final breakdown of the insulation. The constant potential method explained in this paper provides a means for studying the inherent voltage-current-time relations which are masked in experiments using alternating applied potential.*

Part of the material contained in this paper was presented by the writer to the faculty of the Graduate School of Cornell University for the degree of Doctor of Philosophy. The investigation was later continued with the joint support of the Heckscher Research Council and the General Electric Company.

Several methods were tried for obtaining conducting surfaces on the specimens for constant potential tests. An improved method was devised for making tests and experimental results on four materials were obtained. Peculiar reversals were observed in the charge and discharge curves for fused quartz.

The summary of experimental results is followed by suggestions for further research along similar lines.

Apparatus and Procedure

A. New Method of Measurement.

Previously the most precise measurements of the extremely small currents obtained in d-c. tests on good solid dielectrics have involved the use of a quadrant electrometer as a quantitative measuring instrument.

The erratic shifting of the zero point and changing of the sensitivity of an electrometer led the writer to devise a method of measurement which uses the electrometer as a null indicating device, so that changes in sensitivity do not affect the results. The method used is convenient and accurate for a range from 10^{-12} to 10^{-18} ampere, when the current is changing by only a very small percentage over a period of ten seconds or longer.

The object of the tests reported in this paper was to determine curves of electric current flow as functions of time, through certain solid dielectrics, after constant potential had been either applied to or removed from opposite faces of a flat plate of the sample.

The charge and current curves to be expected when constant potential is applied to such a sample are shown in Fig. 1. The great proportion of the charge is stored almost instantaneously, but because the dielectric is not perfect the charge collected continues to increase. The curve of charge will approach a straight line whose slope will be zero if the final conductivity is zero and will be finite if the final conductivity is not zero. The current curve is the first derivative of the charge curve and will have the general character shown. Its shape during the first instants will depend upon the characteristics of the external circuit.

The initial pulse of the current passes in a very small fraction of a second after applying the potential and was not measured in any of the reported tests. For some materials the stored charge continues to increase for weeks after the potential is applied and kept constant. It is this long-time current that has been measured in these tests. When the potential is removed after a long-time charge the currents are similar but reversed in direction.

The currents obtained are smaller than can be mea-

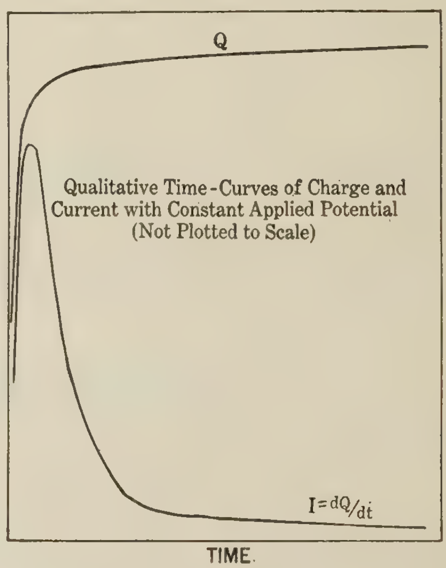

Fig. 1—Qualitative Charges and Current Curves

sured with a galvanometer, so that a circuit using a sensitive electrometer was used. The diagram shown in Fig. 2 will help to explain the method of measurement. C_s is the sample to be tested. C_A is an auxiliary air condenser of known capacitance. P is a potentiometer used to vary the potential applied to the lower plate of C_A. The quadrant electrometer (Q. E.) is used as a

1. Assistant Professor of Electrical Engineering, Cornell University, Ithaca, N. Y.

Presented at the New Haven Regional Meeting of the A. I. E. E., New Haven, Conn., May 9-11, 1928. Complete copies upon request.

very sensitive electrostatic voltmeter to indicate any potential difference between the ground and the isolated system comprising the upper surface of the active area of C_s and the upper plate of C_A.

Before applying potential to the lower plate of C_s the upper system is grounded by closing the ground switch shown in Fig. 2. Then when potential is applied the initial rush of current is conducted through this ground connection.

Now, suppose that after the ground connection has been removed, the slider on P is continually adjusted so as to keep the upper system (though insulated from ground) at ground potential. This is accomplished by so adjusting P that the electrometer spot of light is kept at its zero position. Such an adjustment is possible because any electricity passing from C_s can be drawn onto C_A by properly varying the potential applied to the latter. If at the beginning and end of a certain length of time, the potential of the isolated system is at zero (or any other) potential, all of the current which has passed from C_s in the interval

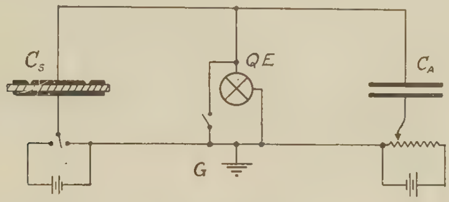

Fig. 2—Simplified Diagram of Connections

will be collected on C_A. The average value of this current will be given by the equation:

$$i_{ave} = \frac{\Delta q}{\Delta t} = C_A \frac{\Delta e}{\Delta t} = C_A \left(\frac{e_2 - e_1}{t_2 - t_1}\right) \text{amperes} \quad (1)$$

where C_A is the capacitance in farads of the auxiliary air condenser and $(e_2 - e_1)$ is the change in potential applied to the lower plate of C_A from P during the interval of time $(t_2 - t_1)$, potential being measured in volts and time in seconds.

For all of the tests the current was considered positive in the direction in which it was normally flowing while a positive potential was applied to the lower plate of C_s. To measure a positive current it was necessary to apply a negative potential to the lower plate of C_A. When the current was reversed, for example during discharge after positive charge, the polarity of P had to be reversed in order to keep the potential of the isolated system zero. During a reading continuous observation of the electrometer scale was necessary; therefore the set-up was so arranged that all switching was remotely controlled from the observer's position behind the scale.

The complete diagram of connections is shown in Fig. 3. (See complete paper.)

Experimental Results

A. With Air-Gap.

As already indicated, the first tests were made with an air-gap between the upper surface of the specimen and the upper plate of the condenser. A plate of hard rubber and one of pyrex were tested in this way.

The charge and discharge curves for hard rubber, are plotted in Fig. 6, using logarithmic scales for both current and time ($C\ H$–2 and $D\ H$–2). It is seen that the experimental data give practically a straight line relationship between log. i and log. t.

$C\ H$–1 and $D\ H$–1 are similar charge and discharge curves taken for a sample of pyrex, nearly 1.5 cm.

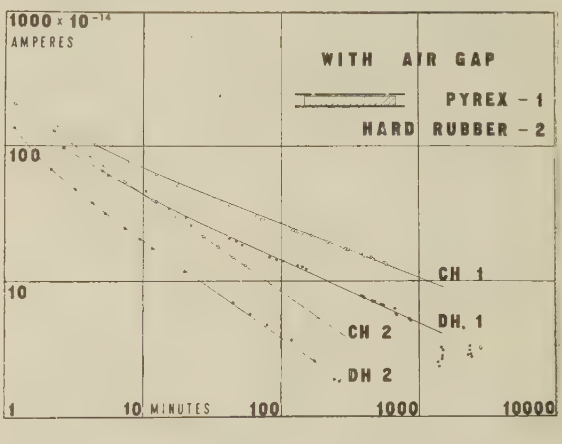

Fig. 6—Hard Rubber No. 7 and Pyrex with Air-Gap

thick. The principal fact to be gained from these is that the straight line relationship makes the polarization an inverse power function of the time:

$$i_p = (\text{const})\ t^{-b} \quad (2)$$

B. With Intimate Contact.

(1) Pyrex—After the curves $C\ H$–1 and $D\ H$–1 shown in Fig. 6 had been obtained, the same specimen

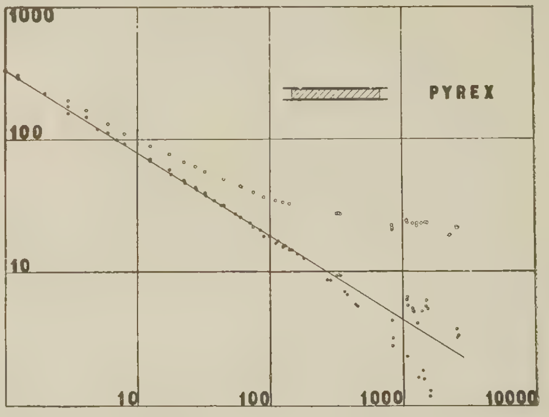

Fig. 7—Pyrex with Intimate Contact

was prepared with intimate contact between the surfaces of the specimen and the plates of the condenser. The results of this latter test, plotted in a similar manner, are shown in Fig. 7.

The upper series of circles, through which no line is drawn, are points on the charge curve which is approaching a horizontal asymptote, the final conduction current

(I_g). In the case of pyrex, I_g is a very appreciable proportion of the charge current.

The series of completely filled dots gives the observed discharge curve, which follows the straight line law for over 100 minutes, after which it drops off more rapidly.

The series of half-filled circles is obtained by subtracting the value I_g from each of the charge readings, obtaining thereby the effect of polarization alone. These lie superimposed upon the points of the discharge curve showing that the phenomenon is reversible. This relationship may be expressed by the equation

$$i_p = i\ (\text{charge}) - I_g = -\ i\ (\text{discharge}) \qquad (3)$$

This relation was stated long ago by Curie[2] as a result of the law of superposition.

The deviation of observed points in Fig. 7 from the

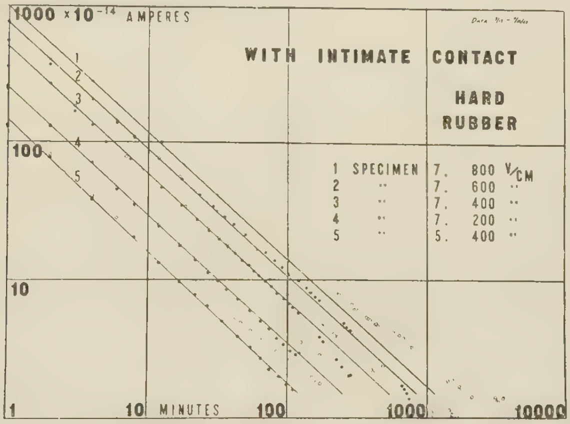

Fig. 8—Hard Rubber No. 5 and No. 7 with Intimate Contact

straight line law may be due to one or both of two causes.

(a) A slightly erratic, unidirectional instrument leak, comparable to the lower values of the curve, was observed. This error decreased the discharge readings but added to the charge readings, the charge current being in the opposite direction to the discharge. The error might well account for the observed departures, for the points of ($i_{CH} - I_g$) lie above the line and the discharge points lie below it.

(b) The other possible explanation is that the reaction of the material actually does not obey the law. This can be determined only by further experiment using more refined methods so as to eliminate possible apparatus errors.

(2) Hard rubber—Fig. 8 shows the results of a series of experiments on two samples of hard rubber. Specimen 7 was tested at four different potential gradients, giving curves 1, 2, 3, and 4. Specimen 5, obtained from a different manufacturer, was tested at only one potential gradient as shown by curve 5. Curves 1, 3, and 4 were taken with a positive potential applied to the lower plate of the condenser. A poor switch contate destroyed the value of the discharge readings for curve 1, so that they were not plotted. Curve 2 was taken with a negative potential applied to the lower plate of the condenser. This shows that the results were independent of the direction of the applied potential.

Because the experimental data indicated that the curves were directly proportional to the applied potential, the lines 1, 2, 3, and 4 were so drawn. They are plotted parallel and apart by distances, so that the ordinates of current at any instant are directly proportional to the applied potential gradient. By observing the agreement of the lines with the observed points, the reader may draw his own conclusions regarding this proportionality.

Curve 5 shows that specimen 5, while having approximately the same time rate of change of polarization as specimen 7, gives less than one-third as much polarization under the same conditions. The composition of these two samples is not known to the writer, so that no deduction may be made as to the reason for this difference.

The values of I_g, taken at the end of each charge curve, included the apparatus errors in the same direction as the actual conduction current. Therefore, the best we may say is that the actual conduction current was equal to, or less than, the observed value; and that the actual apparent resistivity of the material was equal to or greater than that computed using the observed values of I_g (see Table IV).

(3) Fused quartz[3]—

Figs. 11, 12, and 13 show typical sets of data taken

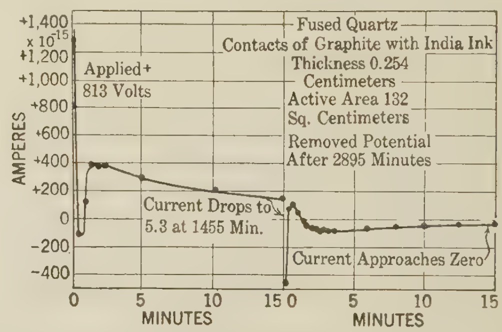

Fig. 11—Fused Quartz with Graphite Contacts

with graphite contacts. The reversals are shown very clearly. The relative magnitudes of the first and subsequent readings for each run are indicated best by Fig. 11, which is plotted using uniform scales. The same set of data is plotted for a much longer time in Fig. 12, using logarithmic scales. The effect of applying a negative instead of positive potential to C_s is shown in Fig. 13.

In Figs. 12 and 13 the curves are broken where they cross the axis, because the scales are logarithmic and no zero can be shown. So far as we could see, changing the contact surfaces did not affect the results, so that they must indicate the reactions of the material itself. It is quite possible that in each case the observed

2. For all references see Bibliography in complete paper.

3. Data leading to these results are shown in the complete paper.

results were preceded by unmeasured oscillations of much shorter period. As an aid in the possible interpretation of these results, the complete history of this sample of fused quartz, for two months preceding the

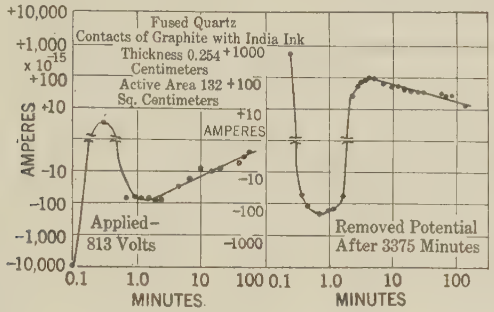

Fig. 12—Fused Quartz with Graphite Contacts

final experiments, is tabulated in Table III. (See complete paper.)

Reversals of Current in Fused Quartz.

Reversals in direction if discharge-current curves, occurring after corresponding reversals of the charging potential, have been observed by numerous investigators. Richardson shows curves demonstrating this effect for a sample of crystalline quartz cut parallel to

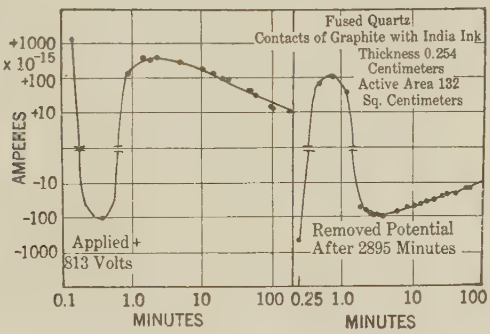

Fig. 13—Fused Quartz with Graphite Contacts

the axis. The law governing the effect was stated in 1889, by Jacques Curie, as the principle of superposition.

However, the results shown in Figs. 10 to 13 cannot be explained by this principle, because the specimen is kept grounded (short-circuited) after each test until it has relaxed as completely as it will; *i. e.*, until the upper plate shows no tendency to acquire a charge in either direction if the ground connection is removed. This is assumed to indicate a neutral or unstressed condition in the dielectric. Then, according to the principle of superposition, if a positive, potential of constant magnitude were applied, the current flow would always be in the positive direction.

Perhaps, upon depolarization, the polarizing elements do not regain truly neutral positions, although they do assume an arrangement which is in stable equilibrium. Thus the reversals observed might be caused by overstraining and slow-time oscillation about a new equilibrium arrangement whenever the applied potential is changed.

The writer is not prepared to offer any other explanation of the results observed, although he believes them to represent truly the reactions of the sample tested. He would be very much pleased to learn whether other investigators have observed similar reactions on fused quartz or other materials.

(4) Crystalline quartz cut parallel to the axis—A plate of clear crystalline quartz cut parallel to the axis was also borrowed from the Bureau of Standards. The contacts on this sample were made by sputtering a gold film in vacuum on the carefully cleaned surfaces. Here

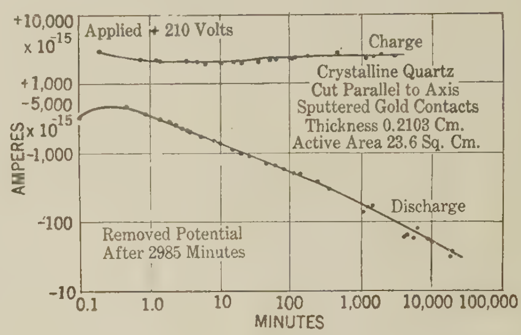

Fig. 14—Crystalline Quartz with Gold Contacts

again, a guard ring was provided. The chief objection to this type of contact is the length of time necessary to get a good conducting film.

Fig. 14 shows the only set of data obtained to date on this sample. The upper curve shows that the final steady current is very high compared with fused quartz. The lower curve shows a return polarization current larger than the charging current for the first minute and a half, and continuing for an extremely long time. In fact, one month after the potential was removed, a discharge current could still be detected, although the plates had been short-circuited for the entire time. This indicates the difficulty of obtaining complete relaxation in such a material. The writer believes that if the charging current had been continued for 100,000 minutes, the lower part of the discharge curve would have continued a straight line instead of falling off as it did.

TABLE IV

SUMMARY OF EXPERIMENTAL RESULTS

All data was taken at temperature of 20 deg.—22 deg. cent.

(1)	(2)	(3)	(4)	(5)	(6)
Hard Rubber No. 7...	200, 400 600, 800	6.5×10^{15}	3.6×10^{18}	550/1	0.924
Hard Rubber No. 5...	400	1.7×10^{16}	3.2×10^{18}	190/1	0.953
Pyrex No. 12.......	200	4.9×10^{15}	8.6×10^{16}	17.5/1	0.6262
Fused Quartz No. 14.	3200	1×10^{18} approx.	8×10^{19}	80/1	0.678
Crystalline Quartz No. 11.....	1000	1×10^{16}	1×10^{16}	1/1	0.525

Column (1) material under test

Column (2) G = applied potential gradient in volts/cm.

Column (3) $\rho_a = \dfrac{e}{i_1}$ = apparent resistivity where i_1 is the current per unit area in amperes/sq. cm. measured 1 minute after the application of potential (see eq. 4).

Column (4) $\rho_f = \dfrac{e}{i_g}$ where i_g was the final constant value of i.

Column (5) ratio of ρ_a/ρ_f

Column (6) coefficient b, when the polarization current is expressed by equation (1).

Abridgment of

Protective Devices

ANNUAL REPORT OF COMMITTEE ON PROTECTIVE DEVICES*

To the Board of Directors:

The principal work of the Committee this year has been *first*,—arranging for and the actual preparation of papers for presentation at meetings of the Institute, of which there have been one or more presented at practically every meeting of the Institute, and *second*,—the work of standardization, the result of which is reported below.

The work of the Committee has been carried on by subcommittees, each under the direction of its own chairman, and after the first organization meeting at New York in September, further meetings have been held by the subcommittees individually. The subjects covered and the chairmen in charge of the subcommittees are as follows:

Current Limiting Reactors, A. H. Sweetnam, Edison Elec. Illum. Co., Boston, Mass.

Communication Circuit Protection, H. W. Drake, Western Union Tel. Co., New York, N. Y.

Industrial Control Equipment and Service Protection, R. C. Muir, General Electric Co., Schenectady, N. Y.

Lightning Arresters, J. A. Johnson, Niagara Falls Power Co., Niagara Falls, N. Y.

Circuit Breakers, Switches, and Fuses, J. M. Oliver, Georgia Power Co., Atlanta, Ga.

Relays, W. H. Millan, Union Elec. Light & Power Co., St. Louis, Mo.

Subcommittee on Industrial Control Equipment and Service Protection

The subcommittee has prepared a revision of the A. I. E. E. Industrial Control Standards. This revision is in process and not sufficiently finished to be presented at this time.

Subcommittee on Communication Circuit Protection

The subcommittee has arranged for several papers and is giving active study to the question of standardization.

Subcommittee on Lightning Arresters

During the last two years much work has been done by the Subcommittee on Lightning Arresters in revising the Report on Standards for Lightning Arresters presented by Working Committee No. 13 in 1926, so that objections raised to the earlier report might be met and still have left something that would give the user of lightning arresters a set of standards which, when applied to arresters, would allow the user to make comparisons on a common basis. This has been impossible in the past.

Such standards must, of course, be based on tests which are feasible to perform in the laboratory at the present time, and while this limitation prevents the establishment of a perfectly ideal set of standards, it does not prevent the setting up of simple methods of comparison which can be carried on in the laboratory, and which will be of value to the user of lightning arresters.

This subcommittee has completed a revision of the proposed standards for lightning arresters, and a full draft of this revision is now being published by the Standards Committee as a report on standards. A complete draft appears also in the complete report of the Protective Devices Committee. After setting up several definitions, the proposed standard undertakes to accomplish its result by the establishment of a standard surge for use in the laboratory, and arresters are to be compared by their action under this surge. This standard surge is given in paragraphs 28-201 and 28-202, and is as follows:

28-201 *Standard Surge Protective Characteristic.*—Tests to determine the standard surge protective characteristic of a lightning arrester shall be made by the use of a test surge, the voltage of which shall be unidirectional and shall rise at the rate stated in 28-202 until the arrester begins to discharge, after which the discharge current through the arrester shall rise at the rate of 100 amperes per microsecond to a crest value of 1000 amperes and thereafter decrease to 500 amperes in not less than 10 microseconds.

28-202 *Rate of Voltage Rise of Standard Test Surge.*—The rate of voltage rise of the standard test surge prior to beginning of arrester discharge shall be as follows:

a. For arresters or arrester sections of low-voltage rating up to 11 kv., 100 kv. per microsecond.

b. For arresters or arrester sections of ratings higher than 11 kv. the rate of rise of voltage of the standard test surge shall be increased proportionately, *i. e.*, 200 kv. per microsecond for a 22-kv. arrester, etc.

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*COMMITTEE ON PROTECTIVE DEVICES:

F. L. Hunt, Chairman,
H. R. Summerhayes, Vice-Chairman,
E. A. Hester, Secretary,

R. E. Argersinger,	Herman Halperin,	W. H. Millan,
Raymond Bailey,	F. C. Hanker,	R. C. Muir,
A. C. Cummins,	J. Allen Johnson,	J. M. Oliver,
H. W. Drake,	R. L. Kingsland,	A. H. Schirmer,
W. S. Edsall,	M. G. Lloyd,	H. P. Sleeper,
L. E. Frost,	K. B. McEachron,	A. H. Sweetnam,
James S. Hagan,		F. D. Wyatt.

Presented at the Summer Convention of the A. I. E. E., Denver, Colo., June 25-29, 1928. Complete copies upon request.

There has been some criticism of this standard surge on the basis that it does not give a sufficiently steep wave front, but there is grave doubt whether a steeper wave front can be produced in the laboratory without oscillations when accompanied by the large currents which are involved in the testing of lightning arresters.

Current Limiting Reactors

Report of Subcommittee

Two interesting developments in current limiting reactor practise involve the use of reactors which are oil-immersed in steel tanks. One development involves the use of a three-phase reactor, oil-insulated, self-cooled, while the other involves a single-phase unit, oil-insulated and water-cooled. The advantages claimed for these designs are that foreign material cannot be drawn into the windings and that the equipment can be used with the highest factor of safety either for indoor or outdoor service.

The single-phase equipments are designed for installation as 22-kv. bus section reactors, introducing a reactive drop of 9.2 per cent when passing 90,000 kv-a. No live parts are exposed, as the coil is mounted in a steel tank, and lead covered cable is to be "wiped" to glands bolted to a junction box, which in turn is bolted to the tank. This method of attachment makes possible the removal of the reactor from the circuit without disturbing the "wiped" joints. Each cable terminal is so insulated that cable sheath currents cannot flow through the tank to ground.

The tank is provided with a conservator, pressure relief pipe, oil gage, thermometer, and standard gage trucks.

The magnetic flux of the reactor which would normally link the steel tank, causing large losses, is neutralized by utilizing the copper cooling coils as a short circuited winding, (the intake and discharge ends of the cooling coils being joined) thus acting as a flux shield. The potential developed in this shield causes a current to flow, which in turn develops an equal but opposite flux. Therefore, no flux enters the tank, and no losses are developed. The material of the cooling coils is a high-conductivity copper tubing of adequate cross-sectional area to permit such currents to flow as will develop the required flux. To neutralize the flux of the reactor coil the current in the shield is limited to a definite value by the inherent reactance of the cooling coils. The losses in the shield are limited by properly proportioning the cross-section of the shield.

Relays

Report of Subcommittee

Three papers have been presented to the Institute during the current year under the auspices of this subcommittee as follows:

Developments in the Impedance Relay and its Application, by H. A. McLaughlin and E. O. Erickson.

Application of Relays for the Protection of Power System Interconnections, by L. N. Crichton and H. C. Graves.

A Carrier-Current Pilot System of Transmission Line Protection, by A. S. Fitzgerald.

The second paper listed was presented both at the Chicago and New Haven Regional Meetings.

The work of this year's subcommittee has consisted chiefly of reviewing the work of previous years and attempting to crystalize work which has been started. In this connection attention is called to the matter of standardizing relay acceptance test specifications. A group of last year's subcommittee submitted tentative test specifications in the annual report and expressed the hope that interested engineers would forward their comments to this subcommittee so that a tentative "Standard" could be submitted at this time.

Very few comments have been received and it is hoped that interested engineers will offer further comments and proposed tests for reference, a complete tabulation of which is given in the full report of the committee.

Another item discussed by this subcommittee during the last two years was the matter of name-plate data. In general, it is agreed that the following information should be available:

a. Descriptive name of relay.
b. Nominal operating current, voltage, or both.
c. Frequency.
d. Manufacturer's type or style designation.
e. Manufacturer's name or trade mark.

In addition to the above, the polarity of directional relays should have studs marked in the same manner as are terminals of instrument transformers. It is further recommended that the following information be available on the card which is usually attached to the relay when furnished.

f. Calibration curve or time setting chart.
g. Volt-ampere consumption and power factor (or resistance and reactance of the various coils).
h. Interrupting capacity of tripping contacts.
i. Resistance values of all resistances furnished with the relay. These values should also be stamped on the name-plate of the resistor.

As questionnaires are unsatisfactory and undesirable, a request is made here for comments on the foregoing.

During the past year many new relay developments have appeared.

The carrier-current pilot protective system has been called to the attention of the engineering fraternity by Mr. Fitzgerald, who assures us that this system offers practically all of the advantages of the well tried pilot-wire system without its most undesirable features.

Induction type relays have been developed for use as power-factor relays, temperature relays, for the control of reactive kv-a. meters, and for the control of street lamp circuits by carrier current. Also a new induction type

relay has been developed to perform on the impedance principle for transmission line protection. This relay has its restraining coil designed on the induction disk rather than the plunger principle.

A speed control relay is now used to facilitate the synchronizing of turbine driven generators. It has double-throw contacts operated by Warren synchronous motors through a differential gear in such a way that if one motor is faster than the other, one contact is closed, and if slower, the other contact is closed. One motor is connected to the bus and the other to the machine being brought up to speed. The contacts control the governor and increase or decrease the machine speed until it corresponds practically to the bus frequency, at which point the machine may be synchronized by another relay or by the operator.

A new polyphase network relay has been developed and along with other things provides a most ingenious method of quickly replacing or testing the relay unit.

Attention has been called to the need of development of relays along certain lines, and we set forth below the specific needs which have been mentioned:

1. A multi-contact relay of the plunger type of a size between the present overcurrent plunger relay and the relay used as an oil breaker closing relay. This device should be either "latching" or "electric release." The contact head should be designed for a complete interchangeability of front and back contacts.

2. A d-c. voltage relay whose pick-up and drop-out values can be accurately adjusted, which will not be affected by a reasonable amount of vibration and whose calibration will not vary by "soaking" or by reversal of potential.

3. Further development of timing relays is suggested as they seem to be the most doubtful. The fan type is somewhat weak mechanically and is limited in length of time. The bellows type is difficult to adjust and will not stay in adjustment as it is easily affected by dirt, temperature, etc. There is considerable distance between the type enumerated above and the expensive motor operated devices. A need is felt for something in between.

4. For automatic transformer stations relays which will measure the total station load are needed. This often results in a requirement for a relay having adjustable back contacts for 50 per cent to 90 per cent of the operating value and having current coils capable of carrying continuously three or four times the operating value. Also these relays should have independent make and break contacts.

5. A reverse current relay having greater sensitivity is needed. For example, it is quite difficult to find a relay which will carry continuously the load current of a generator and yet will operate on the small reversal due to the machine motoring.

6. An impedance relay should be developed for ground protection where the ground current is less than the line load current. Three years ago Mr. W. W. Edson suggested using a *CZ* relay with the voltage restraining element reversed so that it could be operated by the residual voltage of a star-delta potential transformer bank.

Late in the year, this subcommittee was charged with the duty developing Standards for Relays, and the preliminary draft of September 1923 was resurrected to be worked over. This work has been started, but the best that can be hoped for is to have a suitable foundation laid down for the successors of this subcommittee next year.

Along with this is recommended to the successors of this subcommittee:

1. A study of the operating experience due to the use of low-tension potential transformers for relaying high-tension lines where the voltage vectors are not an exact reproduction of what is taking place in the lines protected. The various compensator arrangements are too complex to be 100 per cent reliable.

2. Further study in the matter of relaying a transmission system having two parallel lines which may work in parallel or independently. Various cross-connected schemes will meet the parallel condition, but they fail on the second. Pilot wires would be suitable, but they are expensive. Impedance relays are not suitable for short sections of lines, and they require special consideration when the expected ground currents are less than the load currents.

3. A study of the operating experience in the use of polyphase versus single-phase directional relays.

It is recommended that technical papers be obtained for presentation to the Institute of the three subjects named above.

F. L. Hunt, *Chairman.*

CONTRACT SIGNED FOR NAVY DIRIGIBLES

The Secretary of the Navy, Curtis D. Wilbur, has announced that the Goodyear Zeppelin Corporation's bid of $7,825,000 to build two dirigibles has been accepted. The new airships will be known as ZRS 4 and ZRS 5. Comparison between the only rigid airship now in the Navy Service, U. S. S. Los Angeles, is as follows:

	Los Angeles	ZRS-4
Nominal gas vol., cu. ft.	2,470,000	6,500,000
Length over all	658.3 ft.	785 ft.
Maximum diameter	90.7 ft.	132.9 ft.
Height over all	104.4 ft.	146.5 ft.
Gross lift, lb	153,000	403,000
Useful lift, lb	60,000	182,000
No. of engines	5	8
Total hp	2000	4480
Max. speed, knots	63.5	72.8
Range without refueling at 50 knots cruising speed, naut. miles	3500	9180

Abridgment of

Surge Voltage Investigation on Transmission Lines

BY W. W. LEWIS*

Member, A. I. E. E.

***Synopsis.**—This paper and companion papers discuss the surge voltage investigation on six power systems in the lightning season of 1927.*

Valuable data have been secured as to the nature and polarity, magnitude, wave-front and attenuation of surges; also the effect of overhead ground wires, choke coils, and lightning arresters.

Of special interest is the attenuation formula $A = k\,e^2$, the form of which indicates a close connection between attenuation and corona loss.

Further investigations are being carried on in the present year to secure more complete and exact data on wave shape and attenuation, effect of ground wires, lightning arresters, and choke coils.

IN 1926 the General Electric Company conducted a surge voltage investigation on a limited scale in cooperation with the Pennsylvania Power & Light Company, New England Power Company and Consumers Power Company. Thirty surge-voltage recorders in all were used. In 1927 the investigation was continued with a larger number of instruments on the systems mentioned, and some additional systems were included; namely, the Ohio Power Company, Alabama Power Company and New York Power & Light Corporation. In all, 130 instruments were in service.

This investigation yielded a vast amount of data, which has been sifted and analyzed, and it is the purpose of this and the companion papers[1] to present the more important data and the conclusions to be derived therefrom.

The companion papers present in considerable detail a description of the system and the results of the investigation so far as the Pennsylvania Power & Light Company, New England Power Company, Ohio Power Company, and Consumers Power Company systems are concerned. The investigation on the Alabama Power Company and New York Power & Light Corporation's systems was not so extensive as on the other systems mentioned. Some data were obtained however, and these will be included in the present paper.

Purpose of Investigation

The surge voltage investigation was conducted for the purpose of securing information on the following subjects:

1. Nature and polarity of surges
2. Magnitude of surge voltages on transmission lines due to lightning, switching, and arcing grounds,
3. Wave-front and wave-shape
4. Attenuation of surges along the transmission line,
5. Effect of overhead ground wires in reducing surge voltages[1]
6. Effect of choke coils and lightning arresters.

Each of these items will be discussed in more or less detail.

*General Electric Company, Schenectady, N. Y.

1. For references see end of paper.

Presented at the Summer Convention of the A. I. E. E., Denver, Colo., June 25-29, 1928. Complete copies upon request.

1. Nature and Polarity of Surges.

Surges may be classified as unidirectional and oscillatory. The unidirectional surges may be positive or negative.

The oscillatory surges may further be classified as highly damped, *H D*, medium damped, *M D*, and slightly damped, *S D*. A highly damped figure may be predominately positive or negative.

The *H D* figures are interpreted as being produced by a surge voltage which lasts for only a few polarity reversals, say less than five.

The *M D* figures are attributed to oscillations following flashovers between line conductor and ground. They appeared in this investigation only on the Consumers Power system, which was the only isolated neutral system in the investigation.

The *S D* figures are of uncertain origin. They appear to be formed from a continuous application of a-c. potential for a duration of several seconds. They are thought to be connected with a particular potentiometer arrangement, as they did not appear when simultaneous records were taken with other potentiometer arrangements.

2. Magnitude of Surge Voltages on Transmission Lines due to Lightning, Switching and Arcing Grounds.

a. Lightning. In Table IV are listed the maximum voltages due to lightning; first, all figures, and second, *H D* figures only. In this table is also listed the number of disks, type and impulse flashover of the line insulators as determined in laboratory tests.[4]

It will be noted that the maximum voltage recorded in no case exceeds the impulse flashover values given, but is in most cases comparable in value or somewhat less. This would indicate that the impulse values given are fair values to use in estimating the lightning flashover of transmission lines, and would further indicate that the maximum voltage induced on a line is limited by the insulator flashover.

Fig. 7 shows curves of surge voltages for the various systems due to lightning. In these curves the abscissas represents times normal crest to neutral volts, and the ordinates per cent of the total number exceeding the value indicated by the abscissas. All surges, *H D*,

TABLE IV
MAXIMUM VOLTAGE DUE TO LIGHTNING

	Max. voltage		Line insulation			Ht. of line	
	All figures	*HD* figures	Disks	Type	Impulse flashover kv.	At tower	Average ht. top cond.
Ohio Power Co	1200	475	10–11–12	OB–25622	1180–1400	60–73–86	70
Pa. Pr. & Lt. Co	2100	1800	14–16	Locke 7500	1900–2140	66	50
New England Power Co	900	900	8–9	OB–25620	1020–1120	49	40
Consumers Power Co	1140 +	850	9 K–11 10 H–8	OB–25622	1080–1180	45–58–70 40–46–52	60
Alabama Power Co	610	610	8–9	OB–25622	970–1080	50	40
New York Pr. & Lt. Corp	660	620	8–9	Locke 5800	1150–1270	46–56–66	50

	Kv. per ft. of height	Kv. per ft. required to flash over insulators	Ratio kv. meas. to flash over kv. per cent	Normal voltage crest kv. to neutral	Maximum voltage no. times normal all figures
Ohio Power Co	17	20	85	108	10.2
Pa. Pr. & Lt. Co	42	43	98	180	11.7
New England Power Co	23	28	82	90	10.
Consumers Power Co	19	20	95	114	10.
Alabama Pr. Co	15	27	55	90	6.8
New York Pr. & Lt. Corp	13	25	52	90	7.3

M D, and *S D*, have been grouped in these curves.

It will be noted that the curves have the same general shape, and that the majority of surges are of low value, *i. e.*, less than five times normal.

b. Switching. Table V gives the maximum voltages due to switching classified as to energizing and de-energizing lines.

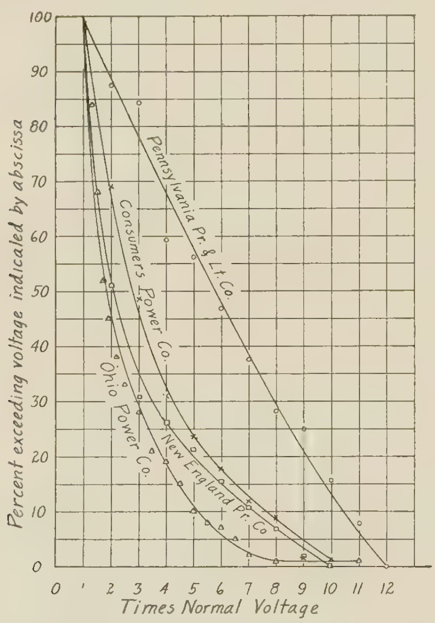

Fig. 7—Magnitude of Surge Voltages Due to Lightning on the Various Power Systems

In Fig. 8 are shown curves of switching surges for three systems, the abscissas representing the number of times normal and the ordinates representing percentage of all surges exceeding the given number of times normal shown on the abscissas.

It will be noted from these curves that the majority of all switching surges were less than three times normal.

In these surges *H D* figures predominated. They were very general throughout a system; that is, they appeared at all the recorder stations and at practically the same value.

TABLE V
MAXIMUM VOLTAGE DUE TO SWITCHING

System	Normal voltage crest kv. to neutral	Energizing times normal kv.	Deenergizing times normal kv.	Both times normal kv.
Ohio Power Co	108	4.2	5.2	
Pa. Pr. & Lt. Co	180	4.0*	Less	
N. E. Pr. Co	90	..	..	4.0
Cons. Pr. Co	114	3.0	3.6	
Alabama Pr. Co	90	1.5	2.6	
New York Pr. & Lt. Corp.	90	Less	3.4	
Average		3.2	3.7	

*On this system all switching was done on the low-tension side.

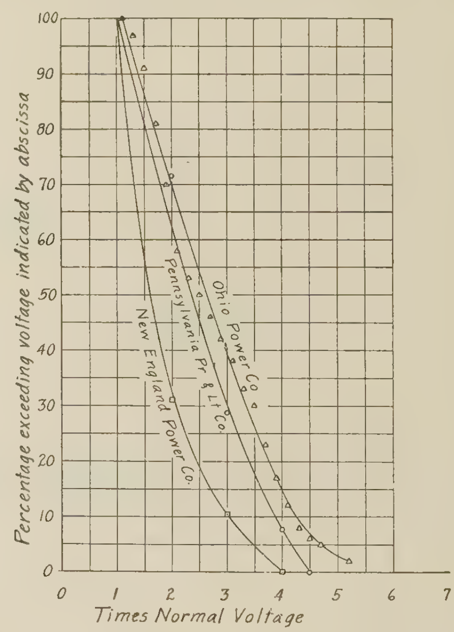

Fig. 8—Magnitude of Switching Surges on Various Systems

4. Attenuation of the Surges along the Transmission Line.

C. M. Foust and F. B. Menger have plotted a number of surges (Fig. 10) which appeared at more than one station, with distance from an assumed origin as

abscissas and voltage as ordinates. They then drew an average curve and determined equations for the variation of voltage with distance, and the rate of change

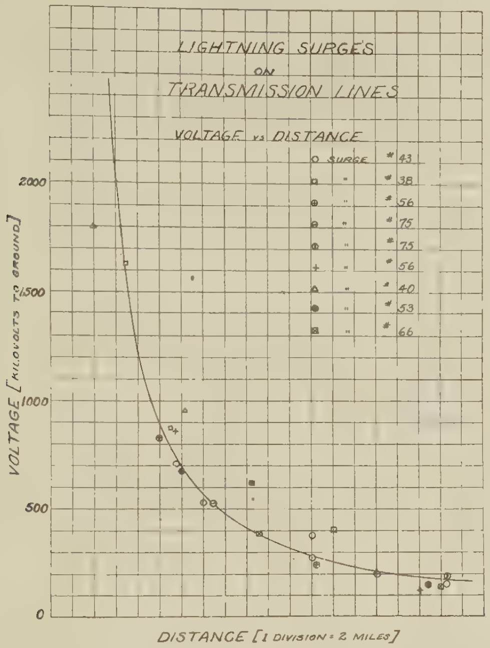

Fig. 10—Curve Showing Variation of Voltage with Distance for Various Surges

Surges 38 and 40 are on Pennsylvania Power & Light Company's system, all others on New England Power system.

of voltage with distance or attenuation. These equations are as follows:

$$e = \frac{e_0}{k\, l\, e_0 + 1} \tag{1}$$

$$A = -\, k\, e^2 \tag{2}$$

in which

e_0 = the initial voltage at the point where the surge originated

k = a proportionality factor which is found empirically

l = the distance in miles from the origin of the surge

e = voltage at any distance l

A = the attenuation in kilovolts per mile.

The factor k for all the surges investigated has been found to be about 0.00016.

These equations are used as in the following examples:

1. Assume the initial potential to be 2000 kv. Then at a distance 10 mi. from the origin:

$$e = \frac{2000}{(0.00016 \times 10 \times 2000) + 1} = 477 \text{ kv.}$$

The attenuation at the point of origin of the surge is $A = -\, 0.00016 \times 2000^2$
$= -\, 640$ kv. per mi.

5. *Effect of Overhead Ground Wires in Reducing Surge Voltages.*

The ground wire data are rather inconclusive, mainly because of a lack of exact comparison between lines with and without ground wires, and also because of the effect of reflections. The surge voltage recorder measures the maximum voltage regardless of whether the maximum is the initial voltage or the reflected voltage. Nevertheless the data have given a few indications of the effect of the ground wire.

Conclusions

Some surge voltages due to lightning are unidirectional and some are oscillatory. Of the unidirectional surge voltages, some are positive and some are negative. Of the oscillatory surge voltages, some have positive characteristics predominating and some have negative.

While there may be a trend in some systems toward certain polarity characteristics, the surge voltages recorded on these systems are not exclusively of these characteristics. It is certain that all unidirectional surge voltages of highest crest value are not of negative polarity, for several of positive polarity have been recorded. High-voltage surges of negative characteristics are, however, in the majority.

The oscillatory surges have been classified as highly damped, *H D*, medium damped, *M D* and slightly damped, *S D*. The *H D* figures are accepted without question. The *S D* figures are of doubtful origin.

The *M D* figures appeared only on one system, which operates with an isolated neutral. These figures reached a magnitude of 7.7 times normal and are thought to be associated with arcing grounds.

Surge voltages of the following upper magnitudes have been measured on the various systems:

Due to lightning, 7 to 12 times normal.
Due to switching, 2 to 5 times normal.

These values check those of previous investigations.[7]

It has been fairly well established that the voltage is limited by the flashover strength of the line insulators which on the average system is from 10 to 14 times normal[4] (normal equals crest value of line to neutral voltage).

Very little is known yet about the shapes of the waves encountered in lightning and other line disturbances. The wave-front varies through wide limits. Of 154 surges examined, about one-fifth had fronts between one and ten microseconds, about one-fifth between 10 and 100 microseconds and about three-fifths over 100 microseconds.

An empirical formula has been derived for attenuation. This is of the form $A = k\, e^2$. That is, the attenuation is faster the higher the voltage. The form of this equation is similar to that for corona loss, $p = c\, e^2$, and indicates that the attenuation is due mainly to corona loss.

The study has shown the benefit due to overhead ground wire in some cases to be very small and in other cases to be almost up to the theoretical value. A conclusive study is very difficult to make, as it is almost impossible to obtain two lines of identical arrangement, in identical territory, subject to the same lightning

conditions, and one with and one without ground wire.

The data as to the effect of choke coils and lightning arresters are meager and more information must be obtained along this line.

The data showed from 6 to 15 per cent difference of potential across the standard line choke coils.

Lightning arresters showed discharge currents varying from 150 to 2600 amperes.

ACKNOWLEDGMENTS

The laboratory work in connection with this investigation was under the direction of Mr. E. S. Lee.

Acknowledgment is due to C. M. Foust, A. L. Price, F. B. Menger, J. A. Tiedeman, R. F. McAtee and others of the General Engineering Laboratory and J. B. McClure of the Central Station Engineering Department of the General Electric Company for their painstaking work in handling, analyzing and correlating the large mass of data accumulated in this investigation. The hearty cooperation of the various power companies is also acknowledged.

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6. "Transmission Line Engineering," W. W. Lewis, McGraw-Hill Book Co., Chapter VII.

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Abridgment of

Gas-Filled Thermionic Tubes

BY ALBERT W. HULL[1]

1. Introduction and Summary. This paper describes a fundamental principle of thermionic gas tube operation, by which cathode disintegration may be entirely avoided; and a new type of cathode which requires much less heat energy than any hitherto used. With these improvements hot cathode gas tubes appear to be practical, and their fundamental characteristics as lamps, rectifiers, and "thyratrons" are briefly described.

The idea of utilizing gas in thermionic tubes is not new. It has been proposed for lamps, rectifiers, and amplifiers; but up to the present time the only successful application is the "tungar" rectifier, which operates within a very restricted range of current, voltage, and gas pressure. Outside of this narrow range, attempts to use gas in thermionic tubes appear to have resulted in unsatisfactory operation and short life. The principal cause of failure has been disintegration of the cathode by positive bombardment, a result so universal that it has come to be looked upon as inevitable.

The starting point of the developments described in this paper was the discovery that *ions produce no disintegration when their kinetic energy is less than a critical value.*[2] The critical value lies between 20 and 25 volts for the common inert gases. Any precaution which avoids the presence of ions faster than this will prevent disintegration. The simplest precaution is to adjust the circuit resistance so that the "cathode drop" does not exceed this critical value, which may be called the *disintegration voltage.* Fortunately, the disintegration voltage in all cases is considerably above the ionizing potential, so that it is possible to obtain the ionization necessary for carrying large currents without exceeding the disintegration voltage. In practise, it is found that the necessary and sufficient condition for keeping the cathode drop within safe limits is that the cathode electron emission shall be equal to the maximum current demand.

The *maximum current* that a tube can carry appears to be unlimited except by the size of the cathode. Cathodes have been made which furnish 1500 amperes emission under conditions which promise long life; and cathodes with a normal emission of 10,000 amperes appear practical.

The *maximum voltage* which can be rectified, or controlled, is limited only by the glow potential of the gas. The rectifiers and thyratrons described below operate satisfactorily at 10,000 volts, d-c. output.

Efficiency and *life* are increased more than ten fold over their values in vacuum tubes by the use of heat-insulated cathodes. A total tube efficiency of 98 per cent, including both anode and cathode losses, at 500 volts operating potential, is easily attained under conditions which promise a life of many years.

Hot cathode controlled rectifiers, or *thyratrons,* in which a grid is interposed between cathode and anode, have been developed. In these an output of several kilowatts may be controlled by the application of one microwatt to the grid.

1. Research Laboratory of the General Electric Co., Schenectady.

2. A. W. Hull and W. F. Winter, *Phys. Rev.* 21, 211, 1923. (Abstract).

Presented at the joint New York Meeting of the New York Sections of the A. I. E. E. and the I. E. S., May 18, 1928. Complete copies upon request.

2. Disintegration Voltage. If argon at 1/10 mm. pressure is introduced into a two-electrode tube with thorium-coated cathode, one obtains a volt-ampere characteristic similar to that shown in Curve 2, Fig. 1. The current rises rapidly with voltage to a maximum value at about 25 volts, and then falls rapidly with further increase of voltage to essentially zero at 125 volts. If the voltage is gradually reduced, the current retraces its path.

The explanation of this characteristic follows at once from Langmuir's theory of thoriated emission.[3] The electron emission is due almost entirely to a single layer of thorium atoms on the surface. The positive ions, whose presence is necessary to neutralize the electron space charge, can be present in the space only by virtue of the fact that they are drifting continually toward the cathode. They strike the cathode with the energy that they have acquired in the electric field, which, at low pressures, is essentially the full-voltage difference between cathode and anode. As long as

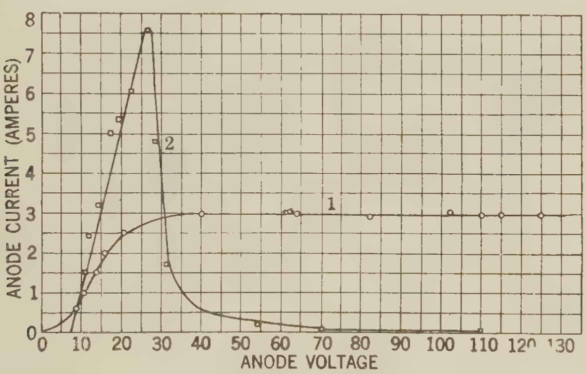


Fig. 1—Volt-Ampere Characteristics of Tungsten Filaments in Argon at 0.030 Mm. Pressure

Curve 1. Pure tungsten at 2450 deg. K.
Curve 2. Thoriated tungsten at 1900 deg. K.

this voltage difference is less than 25 volts, the ions have not sufficient energy to injure the cathode, as is evident from the fact that the electron emission is stable and equal to its value in vacuum. At 25 volts, an occasional ion is able to remove a thorium atom, and the probability of removal increases rapidly with increasing energy of the ions, *i. e.*, with increasing voltage. The loss of thorium is evidenced by decreased electron emission, which falls to essentially zero when half of the thorium layer has been removed.

The significance of this experiment for thermionic gas tubes lies in the fact that *disintegration does not occur when the voltage is below a critical value.* This fact has been confirmed by Kingdon and Langmuir[4] with cold thoriated filaments. They obtained the number of thorium atoms removed per positive ion at different voltages and found that this number fell to zero at a definite voltage for each gas; namely, 45, 47, and 55 volts for neon, argon, and mercury respectively. From experiments similar to those illustrated in Figs. 1-4, with hot filaments and large positive ion currents, I have obtained considerably lower values; *viz.*, 27 volts for neon, 25 for argon, and 22 for mercury. These values are all above the ionization potentials, so that it is possible to produce ionization without disintegration. The problem of making and operating a gas-filled tube without disintegration is thus reduced to that of keeping the voltage drop below these values.

3. Heat Insulated Cathodes. It is well known that the electron emitting efficiency of cathodes increases with temperature, while the life, which is limited by evaporation, decreases.

In the case of high-vacuum tubes there appears to be no other way of greatly increasing the efficiency. No gain can be accomplished by changing the geometrical form, as from a wire to a ribbon, since the heat-radiating area is always the same as the electron-emitting area. Any cavity which conserves radiation, such as the inside of a closely wound helix, also contributes little to electron emission, because the electrons are prevented by the space charge from emerging.

In gas tubes, on the other hand, in which the electron space charge is neutralized by positive ions, it is found that electrons freely emerge from cavities ⅛ to ¼ in. wide and 4 in. deep. This makes it possible to employ cathodes which are heat-insulated on the outside, from which the only appreciable loss of heat is that from the open end through which the electrons emerge.

The economy which can be effected by such heat-insulation of the cathode is illustrated in Figs. 2 to 5.

Fig. 2 shows an "ordinary" type of cathode, consisting of a nickel cylinder coated on the outside with barium oxide, and heated by radiation from a tungsten filament at the center. The efficiency of this cathode is in no way different from that of a filament. Its life is somewhat longer because of the absence of burn-out possibilities, especially that due to "spotting."

Fig. 3 shows an exactly similar cathode, coated on the inside instead of the outside. The electron-emitting area is the same, but only one-third as much heat energy is required to maintain it at the same temperature, hence the efficiency is three times as high. The saving is due to the reduced heat emissivity of its outside surface, the emissivity at 1000 deg. K. of the coated nickel being between 0.65 and 0.85, according to treatment, while that of clean nickel is less than 0.15. The life of the internally-coated cathode may also be expected to be longer by a factor of about 10, since an evaporating barium atom has an average chance of only 1/10 to escape from the cylinder.

Fig. 4 shows the same cathode surrounded by two heat-reflecting nickel cylinders, which further reduce the radiation by a factor 5. This makes the radiation from the surface, exclusive of the open end, only 3 per cent as much as from a black body or 4 per cent of that of a barium-oxide surface; and the total loss, including the open end, $^1/_6$ as much as the cathode of Fig. 2.

The cathode shown in Fig. 5 is the same as Fig. 4

3. I. Langmuir, *Phys. Rev.* 22, 357-398, 1923.

4. K. H. Kingdon and I. Langmuir, *Phys. Rev.* 22, 148-160, 1923.

except that 16 radial vanes have been added, which are coated on both sides with active material, and form part of the electron-emitting surface. Their presence requires no additional heat, but increases the electron-emitting area fourfold. Hence the total efficiency of this cathode is 24 times that of the cathode shown in Fig. 2. It is therefore practical to operate it at a

Fig. 2

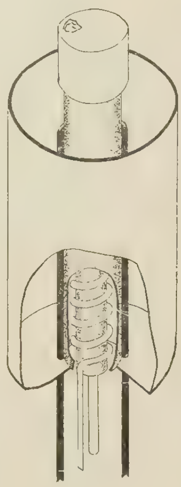


Fig. 3

Fig. 2—Typical Externally-Coated Cathode, Heated by Radiation from a Tungsten Filament at the Center

Fig. 3—Internally-Coated Cathode of Same Dimensions as Fig. 2

The heat loss is only one-third as much

temperature of 1000 deg. K., which would give only 24 milliamperes per heating watt for a filament, but for the shielded cathode gives 600 milliamperes per watt. This corresponds to a circuit loss of only 1.5 volts, which is nearly negligible compared with the arc drop loss of about 10 volts. The life at this temperature would be 55,000 hr., or about 7 years for a filament, and should be greater for a cylinder, which cannot burn out and cannot easily lose its active material.

The same structure is obviously applicable to other types of cathodes, such as thoriated tungsten or molybdenum.

Cathodes of the type shown in Fig. 5 have been in continuous operation for over half a year without noticeable change.

4. *Hot Cathode Lamps.* The use of the hot cathode glow discharge for illumination was proposed by D. McFarlane Moore in 1905. Lederer, in 1914, suggested the use of a Wehnelt cathode in place of Moore's carbon filament for such a glow lamp, and Skaupy in 1915 suggested a tungsten filament. The fact that none of these lamps have come into general use may be attributed to cathode inefficiency and disintegration.

Both of these limitations may be removed by the measures described in Sections 2 and 3 above, and it would appear that there remains no fundamental impediment to the utilization of such hot cathode glow discharges for illumination at any pressure and in any gas that does not dissociate or attack the cathode chemically. Two subsidiary problems, disappearance of the gas and blackening of the bulb, appear to be intimately connected with cathode disintegration[5] and may be expected to disappear with it. The test data available confirm this view. Tubes containing cathodes like those shown in Fig. 5 have been operated for 4000 hr. in Hg. vapor at 0.015 mm. w th no visible blackening; and the neon lamps tested by C. G. Found show no measurable change of neon pressure after 3000 hr. The

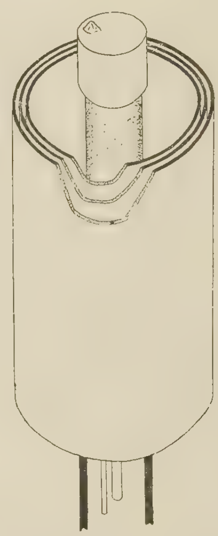


Fig. 4

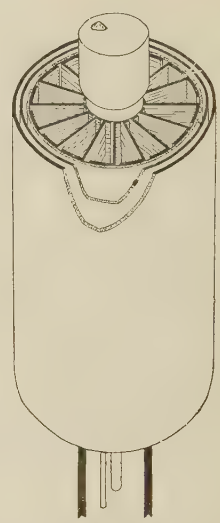


Fig. 5

Fig. 4—Same Cathode as Fig. 3 Plus Heat Shielding Which Further Reduces the Heat Loss by a Factor One-Half

Fig. 5—Same as Fig. 4 Plus 16 Electron-Emitting Vanes which Increase the Electron Emission by a Factor 4

The heat loss remains unchanged

characteristics of hot cathode neon lamps are discussed by Mr. Found in an accompanying article.

5. *Hot Cathode Gas Rectifiers.*

A. *Low-Voltage Tungar Type.* Ordinary Wehnelt type cathodes may be operated in mercury vapor at from 1- to 3-mm. pressure for surprisingly long life at high temperature and correspondingly high efficiency.

5. Contributions from Res. Lab. of G. E. Ltd., *Phil. Mag.* 41, 685, 1921; J. Fischer, *Fortschritte d. Chem.* 19, 1, 1927.

For example, a half-wave rectifier whose cathode is a barium-coated nickel cylinder ¼ in. in diameter by ⅝ in. long, requiring only 25 watts to maintain it at operating temperature, may be operated at five amperes average rectified output for 4000 hr. If operated under the same conditions in Hg. vapor at 1/100-mm. pressure, the life is less than 20 hr. The difference is due to the protective action of the gas, which tends to prevent evaporation of both barium and nickel in the same manner as in gas-filled lamps, and also appears to cause the return to the cathode of nearly all evaporating barium atoms, presumably as a result of ionization by "collisions of the second kind" with excited mercury atoms. This is evidenced by the slow rate of evaporation of barium as compared with nickel. After 4000 hr. this cathode may be reduced by evaporation to a mere lacework, yet retain its full electron-emitting activity. If operated at the same temperature in vacuum, or low-pressure gas, the rate of loss of barium is high compared with that of nickel, so that the electron emission is permanently lost in 20 hr.

This protective action appears to be identical with that which gives to the "tungar" rectifier its distinctive features, and these high mercury pressure tubes are to be classed as tungars. They are capable of rectifying slightly higher voltages than argon-filled tungars, a rectified d-c. output of 500 volts being possible with pressures between 1 and 3 mm. (cf. Fig. 6).

B. High Voltage. For high-voltage rectification, above 1000 volts, it is necessary to use a gas pressure so low that its protective action is negligible. The maximum voltage between anode and cathode which a rectifier can reliably withstand appears to be identical with the sparking potential of the gas at the given pressure, electrode material, and effective electrode distance. The effective distance is that between the pair of points which has the lowest sparking voltage. It is not limited to actual electrode distances, since the presence of positive ions can distort the electric field so that the full voltage may exist, on the one hand, in a thin "sheath," a small fraction of a millimeter thick, next to the cathode[6] (the anode of the rectifier); or, on the other hand, the maximum distance between electrodes along lines of force may be considerably longer than in the absence of ions. The first case corresponds to gas pressures above the minimum sparking potential pressure, the second to pressures below this. In both cases the space charge tends to adjust itself so as to make the sparking potential as low as possible. At high gas pressures the spark length that would give minimum sparking potential is less than the distance between electrodes, and the space charge therefore seeks to shorten the distance to the optimum value. This it can always do, since there is no lower limit to the thinness of the "sheath." Hence the arc-back voltage should be constant and equal to the minimum sparking potential of the gas for all gas pressures higher than that which corresponds to the minimum sparking potential between the electrodes.

For pressures lower than this limiting value, the sparking potential would be increased by shortening the distance, but may be decreased by lengthening the distance. This the ionization tends to do. But there is a definite limit to the possible length, set by the dimensions of the tube. Hence the arc-back voltage at low pressures should increase with decreasing pressure, and at any given pressure should be equal to the sparking potential of the gas at that pressure and at a spark length equal to the maximum possible path between electrodes.

The experimental data available confirm these expectations, for both high and low gas pressures. Fig. 6 shows the results of arc-back measurements in a low pressure rectifier containing a hot cathode and a carbon anode 1 in. apart in a 5-in. glass bulb. The abscissas are mercury vapor pressure in thousandths of a mm., the ordinates the maximum voltage which the tube could rectify without arcing back. The voltage values are maximum or peak voltages between anode and cathode, *i. e.*, the maximum reverse voltage strain which the tube can withstand. These values are quite reproducible.

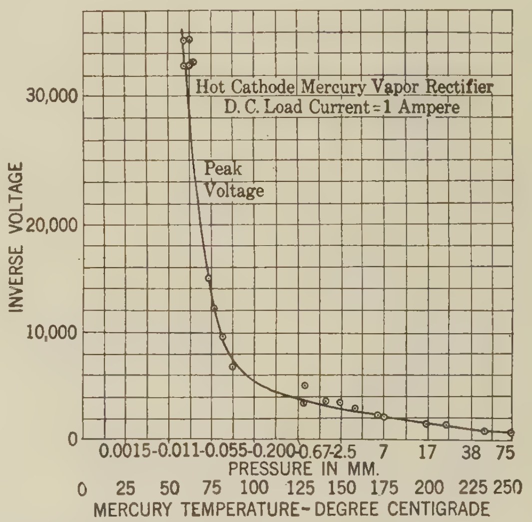


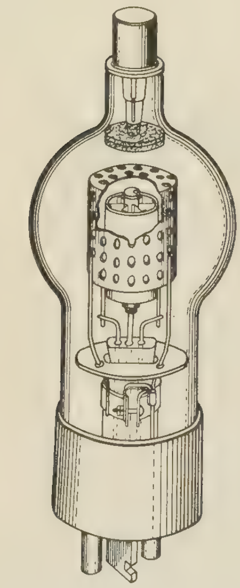
Fig. 6—Voltage (Peak Values) at which Arc-Back Occurs at Different Pressures of Mercury Vapor

In the current-carrying direction the potential difference between anode and cathode is and must be very low. This is the fundamental condition for cathode life, as defined in Section 2. Its importance justifies repetition: *The maximum instantaneous voltage between cathode and anode in the current-carrying direction must not exceed the disintegration voltage.* The actual values for mercury tubes under proper circuit conditions vary between 6 and 12 volts, depending on geometry and gas pressure.

6. I. Langmuir, Science, 58, 290, 1923; *Jl. Franklin Inst.* 196, 751, 1923; *G. E. Rev.* 26, 731, 1923.

From the test data available, which is reviewed in the complete paper, the operating behavior of these rectifiers appears to agree with that predicted. Small of 2000 hr. at 10,000 volts, d-c., output. Larger glass rectifiers have been tested for periods of 100 hr. at 1500 and 3000 volts, with individual outputs of 75 to 150 amperes average rectified current. It is expected that they, too, will operate satisfactorily at 10,000 volts with full output, and that their life will be several years.

6. Thyratrons. The name thyratron, (from the Greek *θ ν ρ α*,—a door), has been suggested for an arc whose starting can be controlled by a grid. It has been known for a long time that arcs could thus be controlled.[7] The characteristics of such controlled arcs have been the subject of an exhaustive study in this laboratory, under the direction of Dr. Langmuir, for



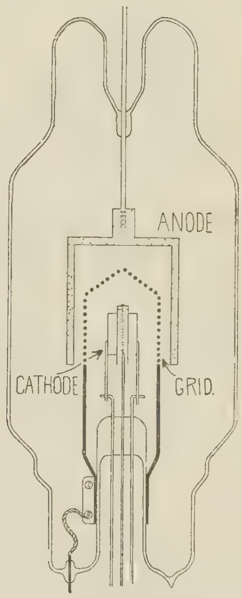


Fig. 7—Typical Hot Cathode Thyratron

The grid must not emit electrons, hence its large size

Fig. 8—Completely Shielded Thyratron

This type of structure gives reproducible characteristics and favors rapid disappearance of ions

rectifiers have been operated satisfactorily for periods several years, and the results of these investigations will soon be published. Only the specific characteristics of hot-cathode thyratrons will be described here.

Figs. 7 and 8 show typical hot cathode thyratrons. Their structure is identical with that of pliotrons except for the form of cathode and the limitations of filament voltage and grid size noted below.

7. I. Langmuir, U. S. Pat. 1,289,823, Dec. 1918; See also L. Dunoyer and P. Toulon, *Comptes Rendus*, p. 179, 1924; *Jl. de Phys.*, 5, 257-68, 289-303, 1924.

Their characteristics also are the same as those of pliotrons when no plate current is flowing, since the distribution of potential in the tube is then obviously the same as in a high-vacuum tube. The amplification factor is defined, in harmony with vacuum tube practise, as the ratio of plate to grid voltage that will just keep the plate current zero. Its value determines at what grid voltage the tube will "start," with a given anode voltage.

As soon as plate current begins to flow the similarity to pliotrons ends. Such factors as mutual conductance and plate resistance do not exist, for the grid is instantly surrounded by a sheath[6] of positive ions, and has no further effect on the current.

This sheath, in general only a fraction of a millimeter thick, contains the whole voltage drop between the grid and the space surrounding it. Changing the grid voltage merely changes the thickness of the sheath, and has no effect on the potential of the rest of the space. Hence the grid is powerless to stop the plate current, once it is started, or to influence it appreciably. The plate current can be stopped only by removing the plate voltage.

The function of the grid is therefore obvious. It is a trigger. If it is desired to turn on a current and allow it to flow thereafter, the thyratron enables this to be done by a very small amount of power. The total energy required to turn on a kilowatt in a tube similar to Fig. 7 is less than 10^{-12} watt-seconds (1/10 micro-watt acting for 10 microseconds.)

When alternating plate voltage is used, the plate current obviously falls to zero at the end of each cycle. The ions which formed the sheaths then diffuse to the walls or electrodes, and at the beginning of the next cycle the process of starting is repeated. No current will flow in this cycle if at every instant the grid voltage is more negative than $\frac{E_p}{\mu}$ where μ is the amplification factor and E_p the instantaneous plate voltage. If at any instant the grid voltage is less negative than this value the plate current will start and flow for the rest of the cycle. The magnitude of the plate current, once started, is limited only by plate voltage and load resistance, not by grid voltage. The *average* plate current, however, may be completely determined by grid voltage, since the grid may allow plate current to flow during any desired number of cycles in each second, or any desired fraction of each cycle. With high-frequency plate voltage the period of averaging may be very short, and if it is short compared with the period of the phenomenon to be observed an essentially continuous control is obtained. Thus audio waves of frequencies up to 5000 may be reproduced with considerable faithfulness by a thyratron with 50,000-cycle plate voltage.

These hot cathode thyratrons have the same characteristics, when carrying current, as the rectifiers described above, and the same requirements, especially as regards disintegration voltage.

In addition, the following special requirements are essential for thyratrons:

1. The maximum filament voltage must not exceed the ionization potential, unless the filament acts as a heater only and is wholly enclosed.
2. The grid must not emit electrons.
3. The grid must shield the whole cathode from the anode.
4. The gas pressure must not be so high that the positive ions persist for a half cycle.
5. Gases which are ionized by contact with a hot filament, like *Cs*, *Rb*, and *K*, must not be present in appreciable quantity.

These limitations are discussed more fully in the complete paper. They do not apply to tubes whose grid mesh is so fine that the positive ion sheaths overlap under operating conditions. Such tubes can be operated in the presence of positive ions, but their characteristics are quite different from those under discussion, and they will not be considered here.

Thyratrons of the type shown in Fig. 7, giving 5 amperes ave. current at any voltage up to 10,000, have been operated continuously for 6 months without change, and a useful life of several years is anticipated. There appears to be no limit to practical size, except that involved in the requirement that the grid shall not unite electrons.

In the development work described in this paper the assistance of the whole research staff has been given but especially of Messrs. W. F. Winter, E. P. Lawsing, H. C. Steiner, and W. A. Ruggles, whose able cooperation is gratefully acknowledge.

Abridgment of

Great Northern Railway Electrification in the Cascades

BY EDWARD L. MORELAND[1]
Fellow, A. I. E. E.
and
RALPH D. BOOTH[1]
Associate, A. I. E. E.

Synopsis.—*The paper gives first a brief history of the series of improvements to better operating conditions over the Cascade Range which have been undertaken by the Great Northern Railway since the line was put in operation in 1893.*

The paper next gives (Part II) a description and the principal operating characteristics of the motor-generator type of locomotives now in service on the electrified section from Skykomish (Washington) to Cascade Tunnel Station, and to be used through the new tunnel and extension of electrification to Wenatchee when work now in progress is completed.

Part III gives a description of the electric transmission and distribution system along the railroad line with particular emphasis on the relay protection designed to guard the system so far as practicable against interruption of power supply at the locomotives.

Part IV describes the three-point power supply and includes a description of the frequency converter stations at Skykomish and Wenatchee for converting the 110,000-volt, 60-cycle, three-phase power purchased at these points to 25-cycle, single-phase power required for the traction service.

Part I.—Introduction

The changes now in process on the Cascade Division of the Great Northern Railway are the latest steps in a series of important changes which have been made since this part of the railroad was put in full operation in 1893, all of which have looked toward improvement of operating conditions on the difficult mountain section over the Cascade range. The present changes include the construction of the new tunnel from Scenic to Berne (7.79 mi. long, the longest railroad tunnel in America), improvement of curves between Berne and Winton, the construction of the Chumstick cut-off from Winton to Peshastin, and completion of electrification from Skykomish to Wenatchee.

The first major improvement in operating conditions over this section was the elimination of switchback operation by the construction of the present Cascade tunnel completed in 1901.

The next major improvement was the electrification of this tunnel in 1909, which was undertaken to eliminate the serious smoke and gas conditions which had developed with increased traffic, and to improve operating conditions for heavy freight trains through the tunnel. This electrification was planned and supervised by Dr. Cary T. Hutchinson, as consulting engineer, and was a three-phase, 6600-volt system with two trolley wires, the rails being used as the third conductor. The locomotives were equipped with three-phase induction motors and could be operated at only two speeds. The steam locomotives were not removed from the trains but were pulled through the tunnel along with the trains. Electric power for operation of the system was supplied from

1. Jackson & Moreland, Consulting Engineers, Boston, Mass.

Presented at the Pacific Coast Convention of the A. I. E. E., Spokane, Wash., Aug. 28-31, 1928. Complete copies upon request.

a small hydroelectric generating station built and operated by the Great Northern Railway at Tumwater, on the Wenatchee River.

In 1925 the officials of the Great Northern Railway decided to take advantage of additional power available from the Tumwater power plant to improve operating conditions by electrifying the heavy grade section from Skykomish to Tye, and utilizing electric helpers on this section. On account of the complication of a double trolley and the operating limitation imposed by constant-speed operation inherent with the three-phase system, that system was not adapted for extension, and a single-phase, 11,000-volt trolley system with locomotives of the a-c.—d-c. motor-generator type was selected by the railroad officials as suitable to utilize the available facilities and to give the required service which included operation of both heavy freight and passenger trains. This scheme employs d-c. traction motors supplied with d-c. power by means of a motor-generator set carried on the locomotive. This system went into operation in February, 1927, over the 25 mi. from Skykomish to Cascade Tunnel Station.

Fig. 1—Map of Electrified System of Great Northern Railway in the Cascade Mountains

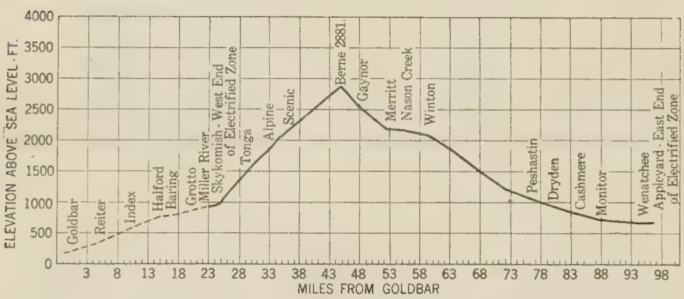


Fig. 2—Profile of Great Northern Railway in the Cascade Mountains after Completion of Present Line Changes

For this service four electric locomotives were provided, descriptions of which are given later. The method of operation, on east-bound traffic, is to pull the trains into Skykomish by steam power, and there, at the foot of the heavy grade section, couple on one or more electric locomotives to pull the trains up the grade and through the tunnel. On account of the relatively short length of the present electrified zone, the steam locomotives are not taken off the trains but are run on through, assisting in pulling up the grade to Tye, but shutting off while passing through the tunnel from Tye to Cascade Tunnel Station. This method of operation has cut approximately three and one-quarter hours off the normal running time of freight trains between Skykomish and Cascade Tunnel Station.

The electric locomotives are also used to take trains down the grade west-bound from Cascade Tunnel Station to Skykomish, utilizing regenerative braking.

Comparatively soon after this improvement was conceived it was decided to improve operating conditions still further by construction of a new tunnel, now nearing completion, and to extend the electrification eastward to Wenatchee.

When these changes are completed the electrification will extend from Skykomish, at the foot of the heavy grade section west of the Cascades (84 mi. by rail from Seattle), to Wenatchee, Wash., a total distance, via the new tunnel, of approximately 72 mi., and all through trains will be operated with electric traction between these points.

Part II.—Electric Motive Power

The motive power for the electrification from Skykomish to Wenatchee will consist entirely of motor-generator locomotives. The railway company now has in use two double-cab locomotives and two single-cab locomotives, and they have on order three more of the double-cab locomotives and two more single-cab locomotives. Each of the locomotives has geared, axle-slung, d-c. traction motors and has motor-generator apparatus which is mounted in the cab on a cab underframe. The single-phase power for the motors of the motor-generator sets is obtained by pantograph from the contact wire at 11,000 volts, 25 cycles. It is transformed to 1240 volts on the double-cab locomotive and to 2300 volts on the single-cab locomotives. Single-phase synchronous motors operating at these respective voltages drive d-c. generators, which supply the d-c. energy to the traction motors.

On the double-cab locomotive the motor-generator set is started by means of the main d-c. generator operated substantially as a series d-c. motor supplied with power from a 125-volt storage battery. When brought up to approximately one-third speed the synchronous motor is thrown on the line at reduced voltage as an induction motor, by which means it is accelerated to approximately 80 per cent of full speed before the excitation is applied. Normal voltage is applied after the motor is in synchronism. The speed of the locomotive is chiefly controlled by varying the voltage of the main d-c. generator by adjustment of its field current by adjustable resistance controlled through contactors. Higher speeds may be obtained by putting the traction motors on to separate excitation, under which conditions the field strength can be reduced approximately 50 per cent.

On the single-cab locomotive a d-c. generator used

for separately exciting the traction motors for regenerative braking is also used as a single-phase series a-c. motor for starting the motor-generator set, in the latter function being connected to a special winding on the main locomotive transformer. The speed of the locomotive is chiefly controlled by varying the voltage of the d-c. generators by adjusting the field current by adjustable resistance controlled through contactors, but the traction motors are equipped with field shunting means, with two operating positions, which permit operation down to 50 per cent of field strength.

A summary tabulation of the mechanical and electrical characteristics of these two types of locomotives is presented in Table I.

TABLE I
LOCOMOTIVE CHARACTERISTICS

	General Electric Co. Single Cab Locomotive	Westinghouse Elec. & Mfg. Co. Double Cab Locomotives
Number of locomotives	4	5
Mechanical		
Classification	1-C+C-1	1-D-1+1-D-1
Total weight each locomotive	518,000 lb.	715,000 lb.
Weight on drivers	409,800 lb.	549,600 lb.
Weight per driving axle	68,300 lb.	68,700 lb.
Maximum rigid wheel base	15 ft. 4 in.	16 ft. 9 in.
Total wheel base	58 ft. 8 in.	78 ft. 11 in.
Height over pantograph locked down	15 ft. 3 in.	15 ft. 10 in.
Electrical		
Number of motors	6	8
Horsepower 1 hr. rating	550 per motor 3300 per locomotive	541 per motor 4330 per locomotive
Tractive effort 1 hr. rating	67,200 lb.	112,500 lb.
Speed full field 1 hr. rating	18.2 mi. per hr.	14.4 mi. per hr.
Horsepower cont. rating	3,000	3,600
Tractive effort cont. rating	60,500 lb.	88,500 lb.
Speed full field cont. rating	18.6 mi. per hr.	15.5 mi. per hr.
Voltage synchronous motor	2,300	1,240
Voltage d-c. generators	750 each, two in series	600
Voltage on traction motors	1500 volts on two motors permanently in series	600 volts all motors in parallel
Capacity of motor-generator set continuous	1-2500 kw.	2-1500 kw. each

Part III.—Electric Distribution System

Contact System. The sections of the railroad included in the electrification consist almost entirely of single main track construction.

Wood pole and bracket construction is used in general for all single track work, except on some curves where cross-span is used. Multi-track construction is of the cross-span type except where guyed structures could not be employed, and at these points wooden poles with expanded metal trusses are used.

The catenary system employed consists of a combination of inclined catenary on the curves and simple catenary with loop hangers on the tangents. A composite main messenger of high tensile strength and a single bronze contact wire are used in all sections except through the New Cascade Tunnel where a copper messenger and a copper contact wire are permissible because of the lower temperature ranges and consequent lower stringing tensions. Bronze contact wires on the system in general were justified, because of high strength rather than for wearing qualities, since the traffic over the line is relatively light.

It was found that 150-foot span lengths could be maintained on tangents and on all curves up to and including 6 deg. Curves of 7 deg. and 8 deg. were designed up to a maximum span length of 120 ft.; 9 deg. curves up to 105 ft.; and 10 deg. curves up to 90 ft.

Bonding. Gasweld bonds have been used throughout the entire electrification. The initial installation employs one 2/0 double-strand U type Gasweld bond per rail joint. The new installation, at present under construction, will employ two No. 2 Gasweld single-strand bonds per rail joint. All special work is bonded with 4/0 bonds. Impedance bonds are installed adjacent to each substation location.

Relay Protection. The protection which is required is against faults in the substation itself, faults on the 11,500-volt contact wire system and faults on the 44,000-volt transmission system respectively.

For the clearing of faults occurring in a transformer substation differential current protection is used, the relays being energized by bushing type current transformers in the incoming 44,000-volt transmission line oil circuit breakers and in the outgoing 11,500-volt trolley feeder circuit breakers.

Protection for faults on the contact wire system and its feeders is provided by one directional impedance type relay in each such feeder.

To guard against the possibility of a sustained high resistance short circuit over heating the transformers the contact making thermometers with which the transformers are equipped, located inside the transformer cases, in addition to ringing an alarm bell, are arranged also to close the trip circuit and cut the substation out of service, if the temperature of the transformer exceeds a predetermined safe limit.

By these two arrangements, adequate protection for faults on the contact system is secured at a minimum of cost.

The protection for the 44,000-volt incoming lines at the transformer substations imposes rather exacting requirements upon the relay arrangement. Each 44,000-volt line is tapped, through a circuit breaker, into a common bus at each of the transformer substations. Consequently, a fault consisting of a ground or of a wire to wire short-circuit occurring on one of these circuits between any two substations requires the circuit breakers at the transformer substations to operate successively in the order of the progression of the substations away from the fault. For example, a fault on Circuit Number 1 between Winton and Tumwater requires the successive operation of circuit breakers at Winton, Berne, Scenic, and Skykomish, in the order given, before the fault is cleared from the system. Two relays are used in each transformer sub-

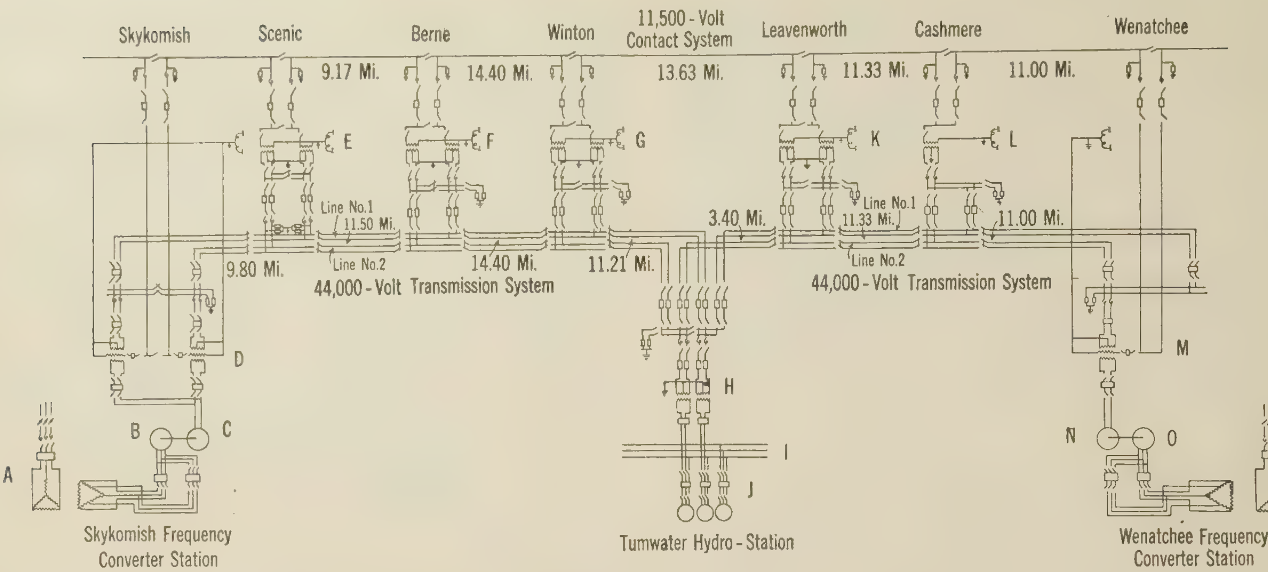


Fig. 3—General Wiring Diagram of Electrification Circuits

A. Three 2750 kv-a. transformers, 60 ~ 110/13.2 kv.
B. Motor 13.2 kv. 60 ~, 3ϕ, 8250 kv-a.
C. Generator 13.2 kv., 25 ~, 1ϕ, 7500 kv-a.
D. Two transformers 7500/5000 kv-a., 44/13.2/11.5 kv.,
E. Two transformers 2500 kv-a. each, 44/115 kv., 25 ~
F. Two transformers 2500 kv-a. each, 44/115 kv., 25 ~
G. Two transformers 1500 kv-a. each, 44/11.5 kv., 25 ~
H. Two transformers 3750 kv-a. each, 6600/44,000 volt, 1ϕ, 25 ~
I. 6600-volt bus
J. Three generators 2500 kv-a. each, 6600 volt, 3ϕ, 25 ~
K. Two transformers 1500 kv-a. each, 44/11.5 kv., 25 ~
L. One transformer 2500 kv-a., 44/11.5 kv., 25 ~
M. One transformer 7500/5000 kv-a., 44/11.5 kv., 25 ~
N. Generator 13.2 kv., 25 ~, 1ϕ, 7500 kv-a.
O. Motor 13.2 kv., 60 ~, 3ϕ, 8250 kv-a.
P. Three transformers 2750 kv-a. each, 60 ~, 110/13.2 kv.

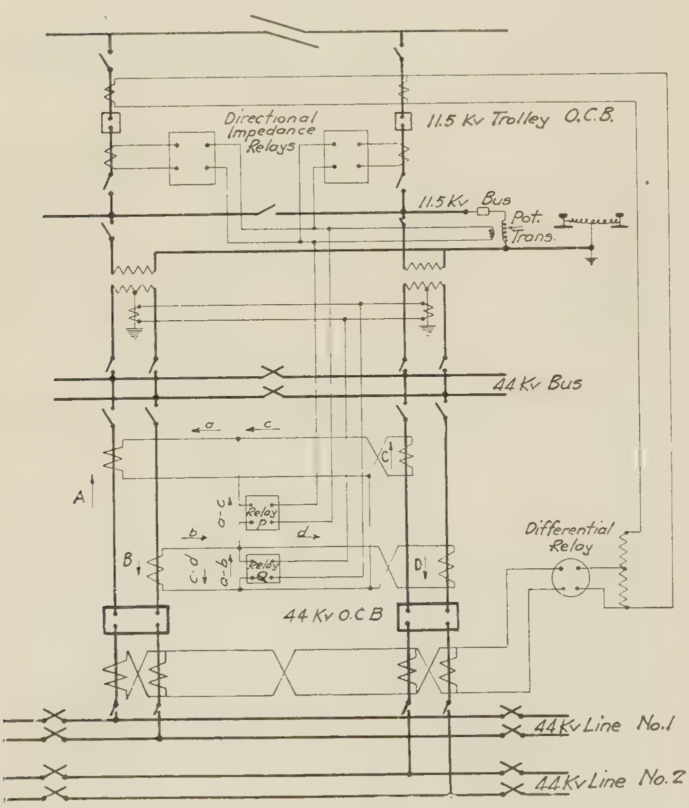


Fig. 4—Transformer Substation Relaying—Schematic Diagram with Tripping Circuits Omitted

Note: All disconnecting switches are normally closed
Current transformers in transformer neutral leads are instrument type
All other current transformers are bushing type
Contact making thermometer in each transformer is arranged to trip all four circuit breakers in case of excess transformer temperature

station to take care respectively of short circuits and ground faults, one (marked relay *P* in Fig. 4) being a directional over-current relay actuated by heavy unbalance between the line currents in the two incoming transmission lines and the other (marked relay *Q*) being a directional over-current relay actuated by slight unbalance between currents in the two transmission lines associated with flow of current in the neutral ground connection of a substation transformer. Fig. 4 shows diagrammatically the connection utilized for these two relays.

Auxiliary locking relays are provided to prevent opening of the circuit breaker on the good line as a result of rebound of the directional element after a circuit breaker on a faulty line has opened.

Part IV.—Electric Power Supply

The power requirements for electric service in the section from Skykomish to Appleyard are materially in excess of the capacity available from the present Tumwater plant. A plan was therefore worked out whereby the Puget Sound Power & Light Company took over the operation of the Tumwater power station and contracted to sell to the railroad all of the electrical service required for operation of the railroad west of Wenatchee. To meet the requirements of the electrification now in operation between Skykomish and Cascade Tunnel Station the power company supplies 25-cycle, single-phase power to the railroad company's step-up substation at Tumwater, and also supplies 60-cycle, three-phase, 110,000-volt power at Gold Bar

for transmission to a frequency converter station at Skykomish, the western end of the present electrification. To meet the added requirements imposed by extension of the electrification to Appleyard (Wenatchee), power will also be delivered by the power company at Wenatchee, at 60 cycles, three-phase, 110,000 volts, where it will be converted to 25-cycle, single-phase power for transmission to the transformer substations. Under the terms of the power contract the demand for billing purposes is determined from the simultaneous demands at the three points of delivery.

Fig. 3 shows in diagrammatic outline the circuit and substation arrangements for the completed electrification from Skykomish to Appleyard.

The plan developed gives three points of power supply, namely, at Skykomish, Tumwater, and Wenatchee, with double circuit, single-phase, 44,000-volt transmission lines connecting the three sources of supply and serving the intervening transformer substations along the railroad route. With this arrangement failure of any one source of supply or failure of both 44,000-volt transmission circuits at any one point cannot cause serious interruption of railroad service.

The two frequency converter stations, at Skykomish and Wenatchee, are supplied with 60-cycle current from transmission lines feeding from two separate points in the power company's system, the line supplying Skykomish coming from the Beverly Park substation, and the line supplying Wenatchee coming from the White River generating station, so that the probability of simultaneous failure of high-tension power supply at Skykomish and Wenatchee is minimized. An interconnection between the Puget Sound system at Wenatchee and the Washington Water Power Company's new hydroelectric plant at Lake Chelan has recently been put in operation and will still further add to the assurance of continuity of power supply.

At the Skykomish frequency converter station power is received at 110,000 volts, three-phase, 60 cycles, and is stepped down to 13,200 volts, three-phase, passed through a 7500-kv-a. frequency converter, which converts the power to 25 cycles, single-phase, at 13,200 volts, which is stepped up to 44,000 volts for transmission to the transformer substations. Each frequency changer is equipped with a stator shifting device.

In the original installation at Skykomish, 25-cycle, single-phase power for the contact system on the railroad was obtained by stepping down from 44,000 volts to 11,500 volts through separate transformers. These separate transformers are now being replaced by tertiary windings on the transformers that are used to step the 25-cycle voltage up from 13,200 volts to 44,000 volts.

The frequency converter station at Wenatchee, which is now under construction, has the same essential characteristics as the Skykomish frequency converter station, and will be provided with a tertiary winding transformer for stepping the 13,200-volt, 25-cycle power up to 44,000 volts for transmission to the transformer substations, and for supplying 11,500-volt power to the contact system at Wenatchee.

The type of construction employed at the frequency converter stations is as simple and inexpensive as is consistent with the reliability requirements.

The transmission system connecting the transformer substations along the line with the frequency converter stations and the Tumwater power station consists of a double-circuit, single-phase, 44,000-volt transmission line running from Skykomish to Tumwater and from Tumwater to Wenatchee, and tapping into the various transformer stations between these points. Over a large part of the route these circuits are carried on the wood poles which support the contact system.

The transformer substations are fed from both of the transmission circuits through oil circuit breakers, and the relaying on the transmission system is so arranged that a fault on any one circuit will remove the circuit complete from Skykomish to Tumwater or Tumwater to Wenatchee, as the case may be, and will open the substation breakers connected to the faulty line, leaving the operation of the substations unimpaired by any single line fault.

The transformer substations along the route are in general of the two unit type, and consist of outdoor equipment with a high-voltage, single-phase, 44,000-volt bus, and a low-voltage, single-phase, single-conductor, 11,500-volt bus. The transformers in each substation in normal operation are tied solidly to the 11,500-volt bus, with the sectionalizing switch in the center of the bus closed. The two transformers at each substation (where two transformers are installed) are hence normally operated as a single unit. The relaying necessary for this method of operation is described in a previous section. This method of operation as compared with operation with the 11,500-volt bus sectionalized permits a more effiective utilization of the transformer capacity, since each transformer is available for service to locomotives on either side of the air section break in the contact conductor, but might not be possible if the right-of-way were closely paralleled by communication circuits.

The detailed plans and specifications for the electrification were prepared by the railroad company's engineering staff under the direction of Colonel F. Mears, Assistant Chief Engineer in charge of the work in the west end of the system, in cooperation with the consulting engineers. The construction work on the extension of the electrification is, with a few minor exceptions, being carried out by the company's own forces. Mr. D. M. Burckett and Mr. J. E. Hawe are the principal assistants of Colonel Mears in direct charge of the electrification work. The construction in connection with the electrification is being carried out under their direction and supervision.

Abridgment of

The Electrolytic Zinc Plant of the Sullivan Mining Company

BY ELLERY R. FOSDICK[1]

Associate, A. I. E. E.

Synopsis.—This paper describes the recently constructed electrolytic zinc plant of the Sullivan Mining Company, located near Kellogg, Idaho. The first unit which has just been completed has a capacity of 50 tons of slab zinc per day. Provision has been made for two additional units which will bring the capacity up to 150 tons per day.

The "Tainton-Pring" electrolytic process, which uses strong acid for leaching and high-current density for electrolysis, is employed in this plant.

The metallurgical process and the physical layout of the plant are briefly described, after which there follows a general discussion of the electrical features.

GENERAL

THE Sullivan Mining Company is owned jointly by the Bunker Hill Sullivan Mining and Concentrating Company and the Hecla Mining Company. It owns the Star Mine, located near Mullan, Idaho. This mine, by means of an 8900-ft. cross-cut, is connected with the 2000-ft. level of the Hecla Mining Company's shaft. A complex silver lead-zinc ore is mined in the Star ground, trammed through the cross-cut, raised through the Hecla shaft, and then shipped to a concentrating mill at Kellogg. The zinc concentrate from this mill is then taken a distance of one mile to the electrolytic zinc plant. Zinc concentrate from sources other than the Star Mine will also be treated, this being a custom plant which will afford an outlet for the refractory and complex zinc ores of the Coeur d'Alene district. Construction on the first unit was started in August 1926 and was practically completed by August 1928.

The erection of this plant is the result of much experimental work in developing a method of treatment for these ores. The plant has a nominal capacity of 50 tons of slab zinc per day but provision has been made for additional units to increase the capacity to about 150 tons daily.

METALLURGY

The Sullivan Plant employs the "Tainton-Pring" electrolytic process, which is based on the use of strong acid in leaching and of high-current density in the electrolysis.

Concentrate. Briefly outlined, the process is as follows: Zinc concentrate is roasted and the roasted calcine is magnetically separated into two parts, (1) a magnetic portion containing most of the iron and the zinc ferrite which is formed in roasting the ore, and (2) the non-magnetic part containing practically all zinc oxide.

Leaching. The magnetic portion containing the zinc which is not readily soluble is added to the hot, strong, 28 per cent acid, which attacks and dissolves the zinc compounds. The oxide portion is then added to this pulp to neutralize the unconsumed acid and to precipitate iron and other impurities which have also been dissolved by the acid.

Purification. The pulp is then filtered. The zinc solution is agitated with metallic zinc to precipitate cadmium, copper, and cobalt. It is then filtered again after which the neutral zinc sulphate solution goes to the electrolytic cells.

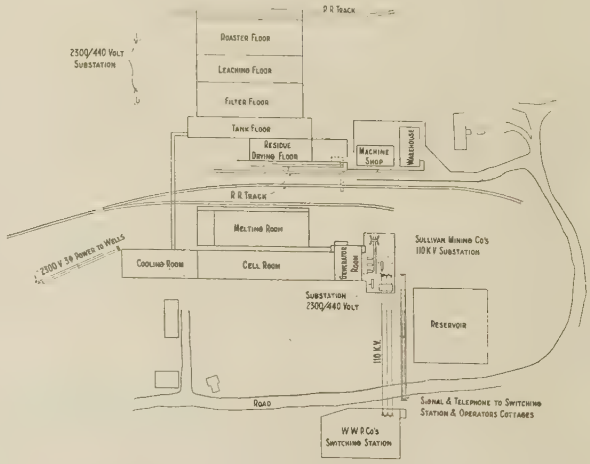


FIG. 2—GENERAL LAYOUT OF ELECTROLYTIC ZINC PLANT

Electrolysis. The electrolytic cells operate at an acid range between 22 and 28 per cent sulphuric acid. When the acid reaches the upper limit, a portion of the solution is withdrawn from the cell solution circuit and a corresponding volume of neutral zinc sulphate solution is added. This reduces the acid strength to the lower limit. The strong acid which is withdrawn is used in the leaching of the calcine as previously described. The process is thus cyclic.

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Presented at the Pacific Coast Convention of the A. I. E. E., Spokane, Wash., Aug. 28-31, 1928. Complete copies upon request.

The heat developed in the electrolysis raises the temperature of the electrolyte. This, therefore, is circulated through coolers consisting of lead-lined boxes in which are placed lead pipe coils through which cold water is flowing. The flow of warm electrolyte is counter current to that of the cooling water in the coils. The electrolyte, after being cooled, returns to the cells in continuous circuit.

Substations

Power Supply. Two transmission lines feed the Washington Water Power Company's switching station,

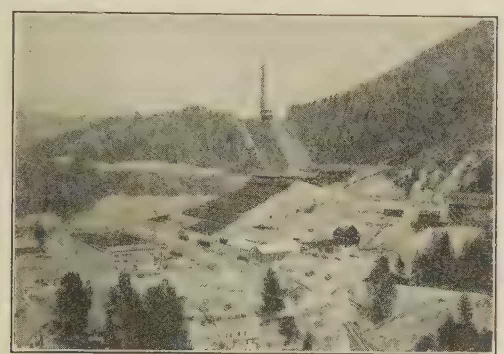

Fig. 3—Another View of Electrolytic Zinc Plant Showing Power Plant

one being a 110-kv. transmission line from the East Side Substation at Spokane, and the other, a 60-kv. line from the Post Falls Generating Plant. The 60-kv. line is connected through a 15,000-kv-a. transformer bank to the 110-kv. line. Continuity of service is further insured by a third line operating at 110 kv., extending from this switching station through the larger substations of the Coeur d'Alene Mining District and at a point near Burke, Idaho, joining the 110-kv. line from the Montana Power Company's Thompson Falls Plant.

Synchronous Motor-Generator Sets

Choice of Generating Equipment. After carefully considering the demand to be made upon them and the reliability of the source of power, two three-unit synchronous motor-generator sets were chosen to supply direct current to the electrolytic cells. Although their efficiency is somewhat lower, it was thought best to use synchronous motor-generator sets instead of booster synchronous converters. The following are some of the advantages in favor of synchronous motor-generator sets for this particular installation:

1. They are more stable, not being affected to such a great extent by surges in the long transmission lines.
2. It is easier to attain automatic regulation with them, as they require fewer automatic features.
3. They have a wider range of voltage.
4. They will correct the power factor of the total plant load.
5. Only one 110-kv. transformer bank and one 110-kv. oil circuit breaker with the accessory equipment are needed. A synchronous converter producing 500 volts, d-c., would not operate at a voltage on the a-c. side which would be suitable for power distribution about the plant. It would therefore be necessary, when using synchronous converters, to have a second 110-kv. transformer bank for this service.

Synchronous Motor-Generator Sets. The synchronous motor-generator sets are of General Electric Company manufacture and supply the current for each electrolytic cell unit of 150 cells. The normal output is 8000 amperes, d-c., at 500 volts. The synchronous motor of the generating unit is rated at 4400 kv-a., 2300 volts; speed, 514 rev. per min. On each end of the motor shaft is a 4000-ampere, 500-volt shunt-wound d-c. generator. A direct-connected exciter supplies field

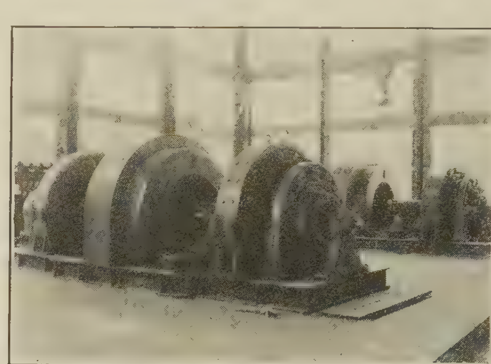

Fig. 4—Synchronous Motor-Generator Set

current for both the synchronous motor and the d-c. generators.

The following tables give the efficiencies of the synchronous motor-generator sets and transformers:

Power factor	Full load	¾ load	½ load	Per cent maximum current load for one min.
1.0	92	91.3	89.0	150

110-kv. transformers

Power factor	Full load	¾ load	½ load
1.0	99.0	99.05	98.95

Including transformer losses, the synchronous motor-generator sets when operating at full load have an efficiency of 91.0 per cent.

D-c. Busses. Direct current is carried from each generator to the circuit-opening devices by five bars at ¼-in. by 6-in. copper. In each generator positive bus is a 6000-ampere, 650-volt d-c. air circuit breaker. Each negative bus has two 3000-ampere, 500-volt knife switches, connected in parallel. After passing through the circuit-opening devices, the two negative busses and

the two positive busses each combine to form a bus of 10 bars of ¼-in. by 6-in copper. These carry the 8000 amperes of direct current to the electrolytic cells in the cell room. The total amount of bus copper used for carrying the current to the electrolytic cells weighs 61,700 lb.

Automatic Regulation. The cyclic variation in the conductivity of the electrolyte, taken in conjunction with periodic shut-downs of electrical apparatus for cleaning, oiling, and brush attendance, made it imperative to adopt some means for obtaining constant kilowatt input to the synchronous motors in order to maintain the desired load factor. Automatic regulating equipment for this purpose was furnished by the General Electric Company, and regulation is obtained in the following manner:

Current transformers and potential transformers in the 2300-volt power cables to the synchronous motors of the motor-generator sets (see Fig. 7 for wiring diagram) have their secondary windings connected to the

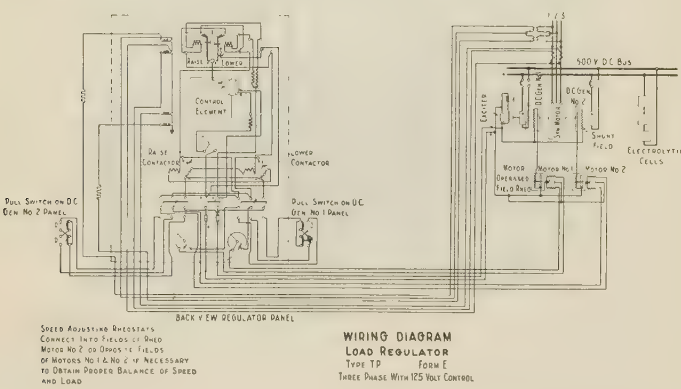

Fig. 7—Rear View of Switchboard Wiring Diagram

control element, or contact-making wattmeter of the automatic regulator which is mounted on a control panel of the main switchboard. This control element, through a timing device, closes one of two pairs of contacts at regular intervals, or does not permit either of them to close until some fluctuation in load causes a change in power taken by the synchronous motor. When a pair of contacts close, they complete a circuit by means of an auxiliary contactor through the field rheostat head driving motors of both generators. The driving motor circuits closed cause the driving motors to rotate the field rheostat brush-arms. This regulates the field current so as to change the generator loads, either increasing or decreasing them as needed, and o changes the power taken by the synchronous motor.

Machine Ventilation. In considering the ventilation of the synchronous motor-generator sets, the usual problem of washing and cooling air was encountered; and in addition to this, it was necessary to make sure that no air was sent through the machines without first going through the air washers.

The gases that leave the stack will have a large amount of sulphur dioxide in them, which being readily soluble, combines with atmospheric moisture to form sulphurous acid. Even though the top of the stack is in a favorable air current and some 500 ft. above the generator room, it may happen that some of this sulphur dioxide and sulphurous acid will be present in the air taken in for machine ventilation. There is also the ventilating air from the cell room which, at times, may contain a mixture of dilute sulphuric acid and zinc sulphate solution. This may also be in the air supplied to the machines; hence, it was thought advisable to wash the air thoroughly to remove both of these and any sulphurous acid which might be present.

A semi-enclosed system of machine ventilation was installed. The generator building itself was used as the enclosure for the machines. Enough cool air is drawn in from outside the building to keep the temperature of the air being drawn in through the washers down to approximately 65 deg. fahr. Air is drawn through the air washers located in the basement, and is discharged into the basement by blowers. This washed and cooled air passes through louvered openings into the machine foundations, is taken up by the machines, circulated through them, and discharged into the generator room. From here, it is drawn down again into the washers, mixing with the desired amount of cool air from the outside to maintain the correct temperature, and the cycle is repeated. The inside of the building is under a static pressure of about ⅛ in. in the generator room and ⅝ in the basement so that any leakage is out of the building rather than into it, which eliminates the possibility of any acid gas fumes around the machines and switchboards to injure insulation or tarnish metal fittings.

The temperature of the air flowing into the air washers is automatically maintained by means of thermostatically controlled louvers, a double set being used, one set opening into the building from the air washer intakes, and the other set opening to the outside of the building. These are mechanically interlocked so that as one opens, the other closes. When cool air is being drawn from the outside, a similar amount of heated air will be discharged through louvers at the top of the building.

Electrolytic Cells

Cell Construction. Each electrolytic cell contains 10 aluminum cathodes and 20 lead anodes. The 10 aluminum cathodes are approximately 1 ft. 8¾ in. by 3 ft. 4¾ in. by 5/32 in. thick, and are suspended in the electrolyte contained in a lead-lined wooden box. Each cathode has two lead alloy anodes, one arranged on each side, and each one spaced ½ in. from the cathode. The anodes which are slightly smaller than the cathodes are approximately ¼ in. thick. Each cell group consists of 150 cells with the electrical circuit connected in series. The present installation consists of two such cell groups. Fig. 8 shows the cells before the anodes and cathodes were installed.

Anodes and Cathodes. The lead alloy anodes are made in the form of flat grids, being perforated with

square holes. The aluminum cathodes are smooth, flat sheets.

Two anodes are used with each cathode,

1. To facilitate the flow of electrolyte between the anodes and cathodes.

During electrolysis the circulating electrolyte enters the space between the anode and cathode through the holes in the anode. By using two anodes for each cathode it is possible to have a space between the two anodes of the two adjacent cathodes from which is taken the supply of electrolyte that is circulated between the anode and cathode. Thus, the zinc content of the solution at all places between the anode and cathode is nearly uniform.

2. To reduce the current density in the anodes and so reduce electrical losses, resulting in higher cell efficiency.

3. To reduce gassing at each anode. More gassing takes place at the anodes than at the cathodes. Excessive gassing at the anodes will result in gas pockets which reduce the amount of surface of the anodes which

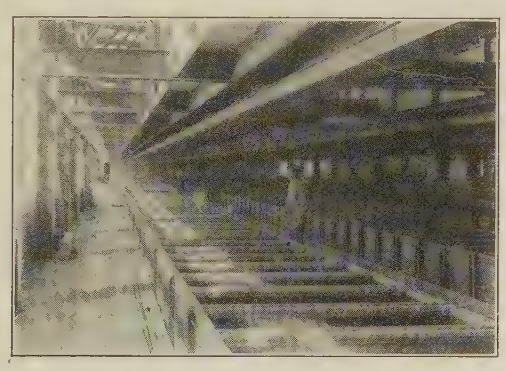

Fig. 8—Electrolytic Cells

are exposed to the electrolyte and so lower the cell efficiency.

Electrolyte. Purified zinc sulphate solution is fed to the cells and recirculated until approximately 90 per cent of the zinc has been extracted from it. The purified solution going to the cells contains over 20 per cent zinc. The liquor returned to the agitator tanks after the zinc is removed contains approximately 28 per cent acid. The cell solution is circulated continuously and at intervals, a portion is removed to the acid storage tanks.

There is parallel flow of electrolyte to the cells; that is, each individual cell of the series is fed from a common supply and the effluent electrolyte from the cells is collected in a common sump from which it is pumped back to the supply tank, thus completing the circuit of flow. The electrolysis is continuous so that the electrolyte is gradually depleted of its zinc content and increased in acidity. In respect to the electrolyte, the process is cyclic in its operation but continuous in respect to the electrolysis.

The decomposition voltage of zinc sulphate is 2.36 volts, but the minimum allowable voltage per cell is 3.1 volts in order that zinc may be positively deposited on the cathodes. Each cell acts naturally as a storage battery, so that if short-circuited, there is a counter e. m. f. of 2.7 volts per cell. There is, of course, a very heavy instantaneous current flow which falls rapidly to zero.

The potential drop per cell depends upon several factors, such as conductivity of the electrolyte, and the spacing and composition of the electrodes. Due to the fact that several of these variables may be subject to change in practise or upon further developments of the process, there is a possible range of 3.4 volts to 3.7 volts per cell with an average of 3.55 volts. These conditions may be met by varying the number of cells in series, and provisions have been made for this in selecting 150 as the number of cells per circuit.

Current Density. The 150 cells of any one unit are connected electrically in series. The 10 cathodes in each cell are connected in parallel and divide the 8000-ampere current flow equally among them. Hence, there are 800 amperes flowing in each cathode, and the current flow at each surface of the cathode is 400 amperes. The current density at each surface of the aluminum cathodes is therefore slightly less than 100 amperes per sq. ft.

Current density in the cells is limited by two factors: (1) It may be as high as the cell will permit without excessive circulating and recurrent cooling of the solution before returning it to the agitator tanks. (2) It is limited by the necessity of keeping down power consumption.

Cell Efficiency. Calculations on zinc tonnage and other factors are based upon 85 per cent current efficiency. Under normal operating conditions, the efficiency is considerably in excess of this, but at times it may fall to 80 per cent due to impure solutions.

Stripping Zinc Deposit. The electrolytic zinc deposited on the aluminum cathodes can be stripped at varying intervals of 12, 18, or 24 hr. The stripping is done without interrupting the circuit. A cathode is disconnected from its clips by being raised and suspended above the cell for drainage of acid electrolyte. The zinc is then stripped from the aluminum cathode and the latter is replaced in its copper clips. A group of five or ten cells in a unit of 150 cells can be short circuited at one time by a copper bar carried on an overhead track. After the short-circuiting bar is in place across the header bars, these cells may be cleaned and repaired before being again placed in service.

Conclusion

Throughout the design of the plant every effort was made so to select and install equipment such as would facilitate flexibility of plant operation. This is particularly desirable in a plant of this type in order that refinements in the metallurgical processes can be added without radical changes to the initial installation.

The writer wishes to acknowledge the helpful suggestions of Messrs. A. C. Stevenson, James B. Fisken, and L. R. Gamble, and the assistance of Mr. W. G. Woolf in the preparation of this paper.

Abridgment of

Surge Voltage Investigation on 220-kv. System of Pennsylvania Power and Light Company

BY NICOLAS N. SMELOFF[1]

Associate, A. I. E. E.

Synopsis.—This paper presents the history of the operating experience and surge voltage recorder data for the years 1926 and 1927, on the first 220-kv. line in the east.

The system of the Pennsylvania Power & Light Company is described. Lightning weather data, design characteristics of the 220-kv. line involved, and details of connection and installation of surge voltage recorders are given.

The study shows the magnitude of surge voltages encountered, method of classification, effect of our overhead ground wires, etc., and points out the necessity for comprehensive lightning research, which will permit a systematic solution of transmission problems.

* * * * *

General

THE system of the Pennsylvania Power & Light Company is located in the northeastern part of Pennsylvania. The present major network and primary distribution is operated at 66,000 volts. Over 50 per cent of this 66-kv. network is on wood pole lines. This 66-kv. system, at present, is connected at Siegfried with the hydroelectric station at Wallenpaupack by means of a 220-kv. transmission line, which was placed in operation in 1926. Although it was the first line operating at this potential in the East, of far more importance is the fact that it was the first 220-kv. line in lightning infested territory, and for this reason it afforded the first substantial experience, with opportunity to study the effects of lightning on a line and equipment insulated for 220-kv. operation.

Lightning Weather Data

The map (Fig. 1) indicates the principal mountain ranges and valleys and the paths of lightning storms during 1927. The solid lines denote the main general paths of the storms, while the broken lines indicate divergencies and show how storms break up and follow different routes.

For the year 1927, this map also shows, the number of lightning storms reported from various locations. From this information it may be seen that the system under discussion is subjected to lightning storms in excess of the average over the country.[2]

Object of Surge Voltage Study

The importance of successful operation of large transmission systems cannot be overemphasized, and the minimizing of the effects of voltage disturbances caused by flashovers due to lightning is of importance. In eastern territory lightning is a major and uncontrollable source of trouble and is the most complicated and least known phenomenon. As a result, the power industry has before it the big problem of lightning research—what lightning is, how to handle it, and how to apply this knowledge in obtaining better line performance.

The comprehensive collection of operating data, supported by data from surge voltage recorders, laboratory research, study, and correlation of facts, will undoubtedly within a few years permit a systematic solution of transmission problems.

The surge voltage recorder is a big and important tool

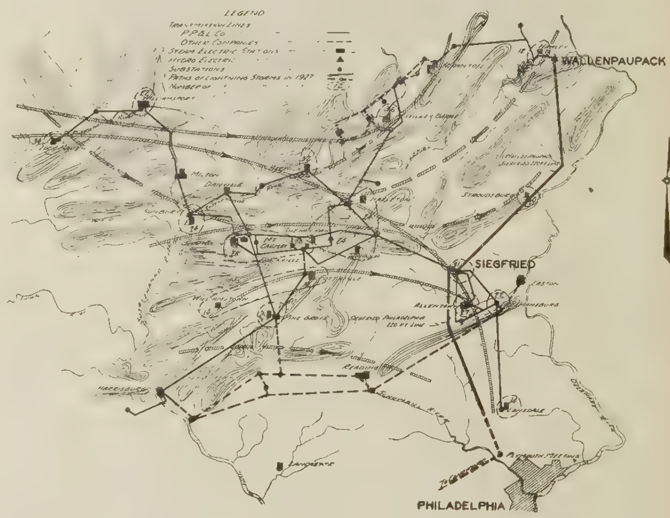

Fig. 1—Map of Pennsylvania Power & Light Co. System

Showing major transmission lines, power plants, substations, and the path and number of lightning storms for the season of 1927

in lightning research in the field. With certain limitations, it permits the study of lightning potentials, wave shape of impulses encountered on transmission lines, attenuation, effect of overhead ground wires, etc. It throws some light, also, on the little known phenomenon of the relation of lightning and power arcs.

Of course the value of the data resulting from the study covered by this paper, (obtained during a short period of time), should not be overestimated, and deductions drawn cannot be considered as indisputable facts. On the other hand, the possibility of

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1. Assistant to General Superintendent, Pennsylvania Power & Light Co., Allentown, Pa.

2. Overhead System Reference Book, N. E. L. A., p. 479, Table 122.

Presented at the Summer Convention of the A. I. E. E., Denver, Colo., June 25-29, 1928. Complete copies upon request.

obtaining a mass of rather conflicting data at the outset should not discourage further studies, as its dependability will increase with the length of period observed; *i. e.*, with the number of lightning seasons.

The Wallenpaupack-Siegfried Line

The terrain crossed by the Wallenpaupack-Siegfried Line is mountainous, quite rugged, rocky, and timbered at its northern end (where a maximum altitude of 2100 ft. is attained) and a rolling farming country at the southern end.

Table I gives the general characteristics of the line,[3]

TABLE I
GENERAL CHARACTERISTICS OF THE WALLENPAUPACK-SIEGFRIED LINE

Frequency	60 cycles
Voltage—	
Between phases	220,000 volts
Phase to ground	127,000 volts
Normal crest volts to ground	180,000 volts
60-cycle flashover (dry)	600,000 volts
Line insulation flashover at lightning voltages, approximately	1,800,000 volts
*Protective gaps at stations—flashover at lightning voltages	1,300,000 volts
Circuits	1
Right-of-way	100 ft. cleared and danger timber cut
Length	65 mi.
Type of construction	Steel tower
Configuration of conductors	22.5 ft. flat
Height of conductors at tower	65.7 ft.
Height of ground wires at tower	75.5 ft.
Average span	1,100 ft.
Maximum span	2,400 ft.
Conductor	795,000 cm. A. C. S. R.
*Ground wire—two	184,000 cm. A. C. S. R.
Insulators—	
Locke No. 7500 high strength unit:	
Suspension assembly	14 units
Tension assembly	16 units
Arc protection and grading	Rings at line end, horns at ground end.
Distance from grading ring to horn of suspension assembly	5 ft. 11¾ in.
Transpositions	See Fig. 2
Relays:	
Wallenpaupack	Overcurrent and ground
Siegfried	Overcurrent and reverse power

*Installed in 1927.

and Fig. 2 indicates the terminal connections and is the one line diagram. Fig. 3 shows the standard "A" type of tower.

During the summer of 1927 (May-July) two overhead ground wires were installed for the approximate distances of 20 miles at the Wallenpaupack (northern) end of the line, and of five miles at the Siegfried (southern) end.

Surge Voltage Recorders

The surge voltage recorder study was made cooperatively by the General Electric Company and the Pennsylvania Power & Light Company. The recorder used was the General Electric two-electrode instrument[4] which makes possible the measurements of transients by positive Lichtenberg figures.

The instrument was connected to the line through a capacitance potentiometer consisting of a string of 20 Locke No. 7500 disk insulators, one end of which was connected to the line and the other to ground. The instrument potential was obtained by a connection to the cap of either the second, third, or fourth insulator from the grounded end of the string depending upon potentiometer ratio desired.

A typical surge voltage recorder installation is shown in Fig. 3. The recorder is installed on an elevated platform, which makes it inaccessible to unauthorized persons. Provision for grounding the instrument when it is serviced, as well as other features, are incorporated to make the installation safe.

The Lichtenberg figures recorded on the photographic films of the various instruments were interpreted as to magnitude, nature, and time of occurrence. Simultaneous registrations on several instruments located at different points along the line have been grouped together and designated as a single surge. The magnitude of the surge voltage on the instrument was determined by figure size, and the magnitude of the surge voltage on the conductor was obtained by multiplying the recorded instrument voltage by the potentiometer ratio. All surge values given in this paper refer to the voltage between the line conductor and ground.

220-Kv. Operation of Recorders During 1926

The 1926 study will be touched upon briefly to give a more complete perspective of the experience with the line under study.

During the 1926 season, the line was operated in two distinct periods,—from April 23 to August 14 at 220 kv., and from August 15, 1926 to March 13, 1927, at 66 kv.

The locations of the instruments were so arranged as to obtain a maximum of data from the limited number of instruments. From Fig. 2 it may be seen that on phase *A*, there were instruments at each end with three along the line at approximately equal intervals. Phase *B* was equipped with instruments only at each end. Table III also contains information on potentiometer ratios used.

During this period a number of severe lightning, storms passed over or near the line. Before the installation of the instruments, five trip-outs were recorded, and after, thirteen trip-outs. After all, except for two apparatus trouble trip-outs, the line was returned to service at will after approximately one minute interval. Of these eighteen trip-outs, one was accidental, two were caused by apparatus troubles at Wallenpaupack, two resulted from flashovers between conductor and yard structural steel at Siegfried during lightning storms, and the remaining thirteen were probably caused by line insulator flashovers. At the

3. "Wallenpaupack Hydroelectric Development," A. E. Silver and A. C. Clogher, *Electrical World*, July 24, 1926.

4. *Measurements of Surge Voltages on Transmission Lines Due to Lightning*, by E. S. Lee and C. M. Foust, A. I. E. E. Trans., Vol. XLVI, 1927, p. 339.

end of the summer season, a careful examination of each insulator string (by climbing towers) disclosed a total of 24 flashed insulators strings. It was impossible to detect most of these flashed insulators from the ground on inspections made after each trip-out. In most cases, the insulator flashovers resulted, in a slight pitting of caps, rings, and horns, and burned and chipped spots on the porcelain, but in no case was an insulator damaged seriously.

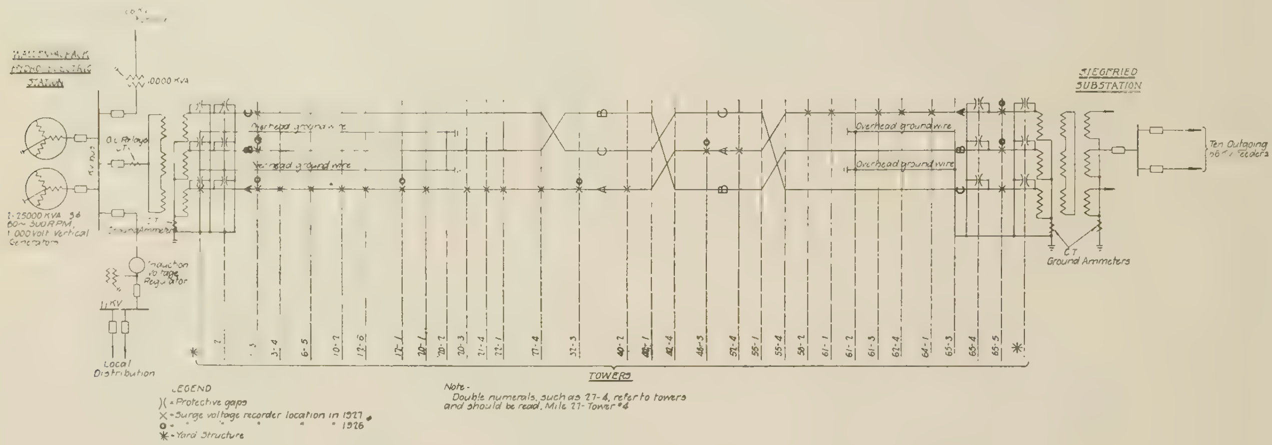

Fig. 2—One Line Diagram of Wallenpaupack-Siegfried 220-Kv. Line and Terminal Stations

Showing locations of surge voltage recorders, transpositions, protective gaps and overhead ground wires

On Fig. 5 is plotted the number of surges against surge magnitude. Of the total of 30 lightning surges recorded, 9 were 10 times normal. Switching resulted in 19 surge records with less than 3 times normal voltage. In addition, there was a total of 14 surges arising from unknown causes, having a maximum value of 1.5 times normal.

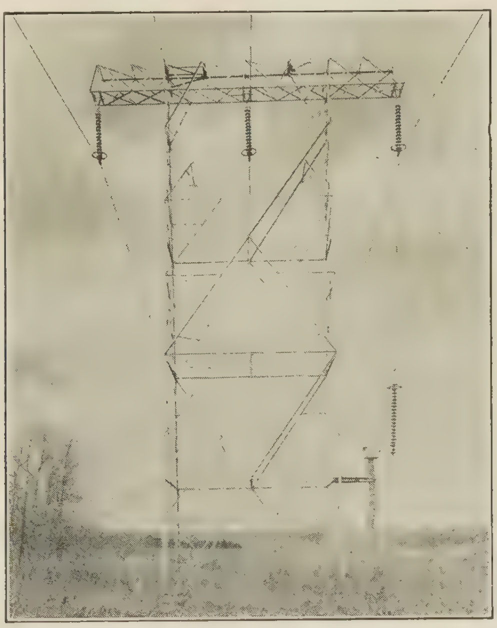

Fig. 3—Typical Surge voltage Recorder Installation

Type "A" tower potentiometer assembly and surge voltage recorder installation

66-Kv. Operation of Recorders During 1926

The 66-kv. operation necessitated a change of insulator potentiometer ratio. The line insulation was also changed from a 14-unit string to a 4-unit string by short-circuiting ten of the insulator units. This reduction of line insulation extended for distances of three miles from Wallenpaupack and of three miles from Siegfried. With the exception of the installation at tower 17-1, the line insulation at each surge recorder station and at one tower on either side was similarly reduced.

A total of three 66-kv. trip-outs was caused by lightning flashover of insulators at tower 1–2 at the Wallenpaupack end on which ten units had been short circuited. Surge voltages recorded showed that a maximum of ten times normal voltage occurred during these trip-outs. The records from the station at tower 17–1, however, showed a voltage 29 times normal (based on

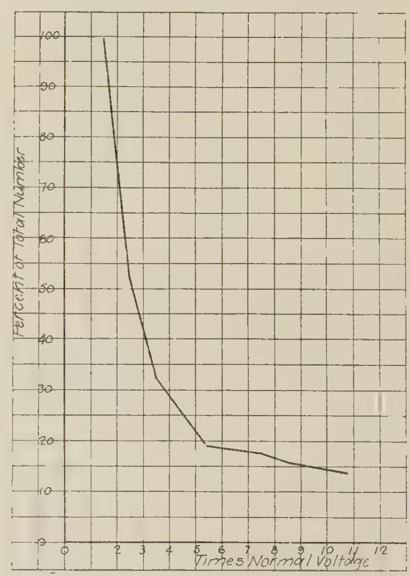

Fig. 5—Magnitude of Surge Voltages 1926

66-kv. line voltage), or 1560 kv. This appears to demonstrate that the insulation to ground is a factor in the determination of the maximum voltage to which surge voltages due to lightning, may arise.

Preventative and Protective Measures

To secure greater safety to the apparatus against lightning surges of dangerous magnitude, two protective measures were adopted during the spring of 1927:

1. The installation, immediately adjacent to the terminal stations, of lightning protective or spillway gaps of approximately 1300-kv. impulse flashover, and

2. The installation, for distances of approximately five miles, at each end of the line of two overhead ground wires.

For the purpose of studying the effects of overhead ground wires and to further reduce the insulator flashovers, an additional 15-mi. section at the Wallenpaupack end of the line was equipped with these ground wires. Thus the line was protected by ground wires for 20 mi. at the Wallenpaupack end, and for five miles at the Siegfried end, leaving the middle section of 40 mi. unprotected. (See Fig. 2). The 20 mi. section contains the highest in point of altitude, and in 1926 more

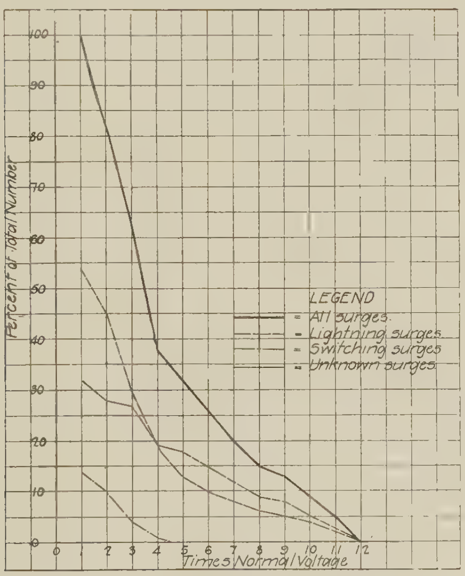

Fig. 6—Surge Classified by Origin 1927

than 50 per cent of insulator flashovers occurred on this part of the line. The overhead ground wire was metallically connected to the station grounds, and at ends away from the transformer stations, it was also effectively grounded through a nest of ground rods. No special provision was made to ground the tower legs.

The protective gaps took the form of insulator assemblies equipped at each end with standard rings having separation of 42.5 in. These gaps were located on the transformer structures and on the first suspension towers at both stations.

1927 Study

During the 1927 season, there were three distinct periods of operation. From March 13 to May 27, the line was operated at 220 kv. without overhead ground wires; from May 27 to July 25 it was deenergized and grounded for the purpose of installing the overhead ground wires; and after July 25 operated at 220 kv. with two overhead ground wires as described.

Location of Recorders. By the close of the season, a

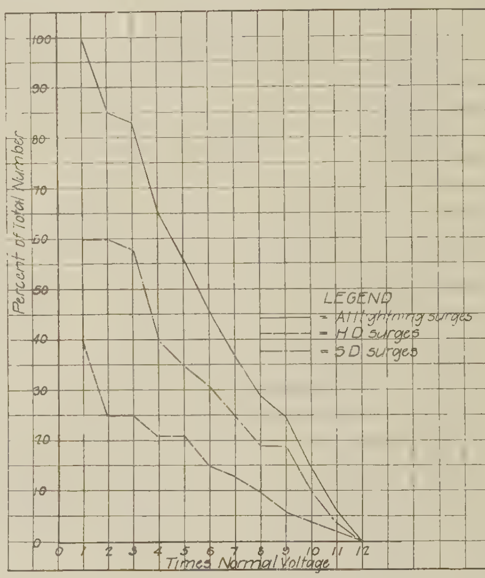

Fig. 7—Lightning Surges 1927

total of 34 instruments was connected to the line as shown on diagram, Fig. 2.

Nature of Surge Voltages. The surges were classified as highly damped (HD) and slightly damped (SD).

The "highly damped" figures are interpreted as being produced by a surge voltage which lasts for only a few reversals of polarity, such as less than five. The "slightly damped" figures are of uncertain origin. During the period the line was grounded and deenergized, no SD figures were recorded. In this period, however, HD figures were quite frequently recorded during lightning storms.

During the 1927 investigation, a total of 149 surges was recorded, ranging in magnitude from 1 to 11.6 times normal (180 kv. to 2100 kv.).

Fig. 6 shows the number and maximum voltage of surges classified according to origin.

Lightning Surges. Fig. 7 shows that 56 per cent of the lightning surges exceeded five times normal. The classification as to polarity shows that there are comparatively few unidirectional surge voltages, although their magnitude may be quite high. The majority of lightning surge voltages on this system were oscillatory, with no definite tendency for either the positive or negative wave to be higher.

The curves of Fig. 7 show the relation between number and magnitude of surge voltages recorded.

On Table VI it may be seen that all unidirectional voltages recorded have HD characteristics. Negative polarity prevails in the HD oscillatory surge voltages in 9 out of the 13 cases. The SD figures, however, show only two of negative polarity out of a total of 30. The

TABLE VI

POLARITY OF HD AND SD SURGE VOLTAGES PRODUCED BY LIGHTNING

1927

Polarity	Number	Highest crest value — Times normal
(a) Unidirectional		
HD Positive	2	10
HD Negative	3	1.9
SD Positive	0	0
SD Negative	0	0
(b) Oscillatory		
HD:		
1. H. C. V. *Positive	4	8.6
2. H. C. V. Negative	9	10.0
3. H. C. V. Positive and Negative equal	0	0
SD:		
1. H. C. V. Positive	7	11.7
2. H. C. V. Negative	2	11.6
3. H. C. V. Positive and Negative equal	21	11.6

*H. C. V.—Highest crest value.

HD figures in no case show equal magnitude of positive and negative voltages, whereas 20 out of the 30 oscillatory SD surge voltages are of equal positive and negative value.

Fig. 8 shows the profiles of typical HD surge voltages. Surge No. 38 occurred on July 26 during a general lightning storm after the ground wires were installed.

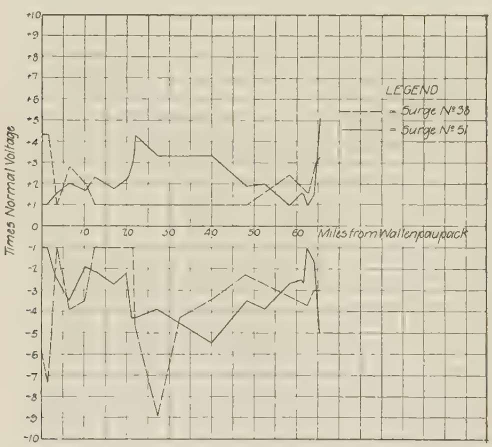

Fig. 8—Voltage Profiles of HD Lightning Surges

The transformer oil circuit breakers at both ends tripped with ground current indication at both stations. Relays indicated trouble on phase *C*. The protective gap on phase *C* at the yard structure at Wallenpaupack flashed over where a number of insulator units was blistered and the shell of one unit broken.

Surge No. 51 occurred on August 13, 1927, during a general lightning storm, however, no trip-outs followed.

These profiles give only an approximate and possibly an incorrect idea of the attenuation along the line. In this connection, it must be borne in mind that there are a great many unknown factors involved. While these curves are based on simultaneous recordings on the instruments as the film moves slowly, there is a possibility that the voltage readings obtained were actually caused by a number of discharges occurring within a short time interval. Further, the recorder actually measures surge potential between line and tower. The location of neutral potential or "good ground" is uncertain. In dealing with surge voltages of very steep wave-front, ground resistances, although low, may be effective in determining potentials between line and tower. The position and extent of cloud charge is also unknown.

Conclusions

1. During the investigations of 1926 and 1927 surge voltages of a magnitude of 2100 kv. were recorded during lightning storms.

2. The majority of surge voltages due to lightning were oscillatory, although a few HD unidirectional surge voltages were recorded.

3. The highest voltages recorded check fairly well with the prediction made from results of insulator calibration in the laboratory.

4. The line insulation apparently limited the magnitude of lightning surge voltages.

5. Not all of the maximum lightning surge voltages caused power arcs.

6. No definite or reliable information was obtained on attenuation.

7. The quantitative value of protection afforded by the overhead ground wire cannot be deduced from the limited data.

8. The highest surge voltages correlated to switching was four times normal (720 kv.), with practically all surges produced by energizing the line. All such voltages were of the HD nature.

9. Many surge voltages were recorded with no possibility of assigning a definite cause to them. These voltages reached an extreme magnitude of 11.6 times normal (2100 kv.).

Future Study

The surge voltage recorder study is being continued in 1928, and it is expected that more data will be obtained than in previous years. The 220-kv. switching also may furnish some valuable and interesting information. Furthermore, with the assistance of laboratory research, it may be possible to determine the relation and condition under which a lightning flashover will be followed by a power arc. This information is of importance in designing lightning proof lines.

Acknowledgment is made to Messrs. C. M. Foust, A. L. Price, F. B. Menger, and W. R. Kleckner for analyzing and correlating the surge voltage data, and to Messrs. A. E. Silver, W. W. Lewis, E. S. Lee, W. E. Lloyd, Jr., and C. A. Jordan for directing the study and criticizing this paper.

Abridgment of

Heat Flow From Underground Electric Power Cables

BY NEIL P. BAILEY[1]

Non-member

Synopsis.—*The heat resistance of the soil surrounding underground cable ducts is usually large, and the path of the heat through the soil is not simple, especially when there are several adjacent ducts. This heat resistance and the path of the heat flow may be determined graphically, but except in the simpler cases, this method becomes very difficult.*

The heat resistance of any one of several ducts can be calculated theoretically by making assumptions of unknown magnitudes. To check these calculations by testing actual installations would be slow and expensive. Advantage may be taken of the similarity between the flow of heat and the flow of electricity to set up and test the electrical equivalent of any duct system. In this way, the theoretical results can be checked readily with a minimum outlay of equipment.

Results obtained by this method show the theoretical calculations to be accurate even for close spacing and also give a picture of the actual path of the heat from a group of several ducts. Thus, the heat resistance of a duct may be found quite accurately if the specific heat resistance of the soil is known.

Object

SINCE the current-carrying capacity of an underground electric power cable is usually limited by heating, it is desirable to understand the manner in which this heat is dissipated. It must obviously pass through the cable insulation and sheath and across the air-space to the duct. Up to this point the path of the heat is quite definite and it is not affected by surrounding cables. After the heat leaves the duct, however, its path is not so obvious, and the heat flow from one duct is affected by that from adjacent ones.

It is the object of this paper to present experimental verification of theoretical methods of calculating the heat resistance of the earth surrounding underground cable ducts.

Symbols

Q = Rate of heat flow per unit length of duct
T = Temperature
r = Duct radius
p = Any radial distance from the center of a duct
S = Specific heat resistance
C = Specific heat capacity
t = Time
d = Depth of a duct below the ground surface
l = Spacing between duct centers
R = Heat resistance per unit length of duct.

Direction of Heat Flow

The study of the heat flow from the ducts is facilitated by considering them as new cylindrical heat sources. Also, it is usually permissible to assume that the ducts are buried directly in the soil, since the heat resistance of the materials in which the ducts are commonly set is very close to that of most soils. (See Appendix B.)

In the case of a duct whose length is great compared with its diameter, it is evident that the heat will flow out radially into the soil. However, since the surface of the ground is within a few feet on one side, and there is an infinite extent of earth on the other, the heat will not flow out uniformly in all radial directions.

An idea of this heat distribution may be obtained by studying the heat flow from a duct surrounded by an infinite extent of soil in all radial directions.

Consider an annular ring of soil of specific heat resistance S and thickness $d\,p$ at a distance p from the center of the duct, of radius r. The heat resistance of this ring per unit length is given by,

$$d\,R = \frac{S\,d\,p}{2\,\pi\,p} \tag{1}$$

Since the soil extends an infinite distance in all radial directions, the total heat resistance per unit length of duct is,

$$R = \int_r^{\infty} \frac{D\,d\,p}{2\,\pi\,p} = \frac{S}{2\,\pi} \log_e \frac{\infty}{r} = \infty \tag{2}$$

From this, it is evident that in the case of an actual duct, no heat will flow downward after the transient period is over, for to do so it would have to flow into an infinite extent of soil.

Graphical Method of Calculating Heat Resistance

Knowing that all of the heat from a linear underground heat source flows to the surface of the earth, it is possible to solve for the heat resistance graphically. As shown by Fig. 1, the ground surface may be considered as an equi-temperature surface. Other equi-temperature surfaces may then be drawn in arbitrarily.

Lines of heat flow must cross these surfaces at right angles, for otherwise, heat would be flowing without an accompanying temperature drop. If the rectangles between equi-temperature surfaces and lines of flow are squares, ($m = n$ in Fig. 1) and if the plot is for a unit

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length of source, the resistance of each square is numerically equal to the specific resistance of the soil. The resistance of each tube may be found from the number of squares in series, and the total resistance from the number of tubes in parallel.

The beauty of this method is that it is independent of the cross-section of the source, as indicated in Fig. 1.

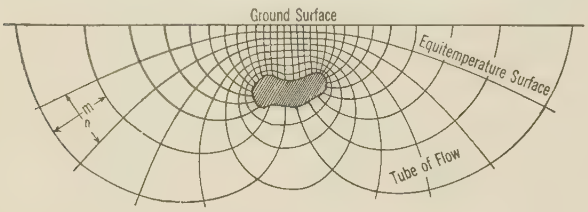

FIG. 1—GRAPHICAL METHOD OF CALCULATING THE HEAT RESISTANCE FOR ANY LINEAR UNDERGROUND HEAT SOURCE

The chief difficulty is that it becomes increasingly tedious as the number of ducts is increased.

THEORETICAL EQUATIONS FOR CYLINDRICAL SOURCES

Theoretical expressions for the heat resistance of underground ducts may be derived as follows:

The heat flow from a line source to the earth's surface may be represented by the lower portion of Fig. 2 which is a line source from which the rate of heat flow is $+Q$, per unit length of source. If the earth's surface is considered as a zero temperature plane, this same field of flow may be realized by replacing the ground surface by an image of the line source at an equal distance

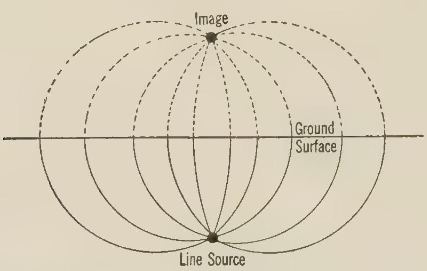

FIG. 2—GROUND SURFACE REPLACED BY THE IMAGE OF A LINE SOURCE

above the surface. If the heat flow from the image is $-Q$ and the system is placed in the soil, the plane previously occupied by the surface of the ground will remain a zero temperature surface, and the heat flow from the original line source to this surface will be the same as before (see Fig. 2).

Making use of the principle of superposition, the temperature difference between any point and the zero temperature surface is that which the point would have due to the heat flow $+Q$ leaving the line charge radially and undistorted, plus that due to the heat $-Q$ flowing radially from the image.

Consider the point A in Fig. 3. When only the line source with a flow per unit length of $+Q$ is acting, the heat flows radially. The temperature drop across an annular ring of thickness $d\,p$ at a distance p from the source is,

$$\frac{Q\,S}{2\,\pi\,p}\,d\,p$$

The temperature difference between A and the zero temperature surface is,

$$\Delta\,T_1 = \int_{d_1}^{h} \frac{Q\,S\,d\,p}{2\,\pi\,p} = \frac{Q\,S}{2\,\pi}\log_e\frac{h}{d_1} \tag{3}$$

In a similar manner, the difference in temperature between A and the zero temperature surface due to the flow $-Q$ from the image acting alone is,

$$\Delta\,T_2 = \int_{d_2}^{h} \frac{-Q\,S}{2\,\pi\,p}\,d\,p = \frac{-Q\,S}{2\,\pi}\log_e\frac{h}{d_2} \tag{4}$$

Thus, the temperature difference for both acting simultaneously is the sum of these two, or

$$\Delta\,T = \frac{Q\,S}{2\,\pi}\left[\log_e\frac{h}{d_1} - \log_e\frac{h}{d_2}\right]$$

$$= \frac{Q\,S}{2\,\pi}\log_e\frac{d_2}{d_1} \tag{5}$$

So far, only a line source has been considered, and the

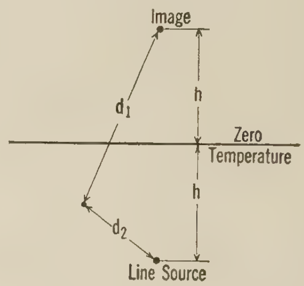

FIG. 3

actual case is that of a cylindrical heat source. By neglecting distortion, the line source may be considered as being at the center of the duct, and the duct surface will be approximately an equi-temperature surface. This assumption could be avoided by further refinement, but it was not found to be necessary.

Upon this basis, the temperature of the duct surface above the temperature of the ground surface for a duct of radius r buried at a depth d becomes,

$$\Delta\,T = \frac{Q\,S}{2\,\pi}\log_e\frac{2\,d}{r} \tag{6}$$

The resistance R per unit length of duct is,

$$R = \frac{\Delta\;T}{Q} = \frac{S}{2\,\pi}\log_e\frac{2\,d}{r} \tag{7}$$

In a similar manner, the heat resistance per unit length for any duct arrangement may be calculated. The temperature of any duct above that of the ground surface is the sum of the temperature differences due to the heat flow of each duct and image acting alone.

Appendix C gives the theoretical equations for three and six ducts.

Since in these theoretical equations all effects of distortion are neglected, it is the chief aim of this paper to investigate the accuracy of such equations.

Experimental Verification of Theoretical Equations by Electrical Analogy

The laws governing the flow of heat are the same as those governing the flow of electricity, and the only difference between the equations of the two is one of units. The equations or the flow of heat through the soil are exactly similar to the equations for the flow of d-c. electricity through a conducting solution.

Advantage was taken of this fact to check experimentally the theoretical equations previously derived. To run a comprehensive set of tests on actual cable installations would be a slow and expensive procedure, while the equivalent electrical circuits can be set up and tested very readily.

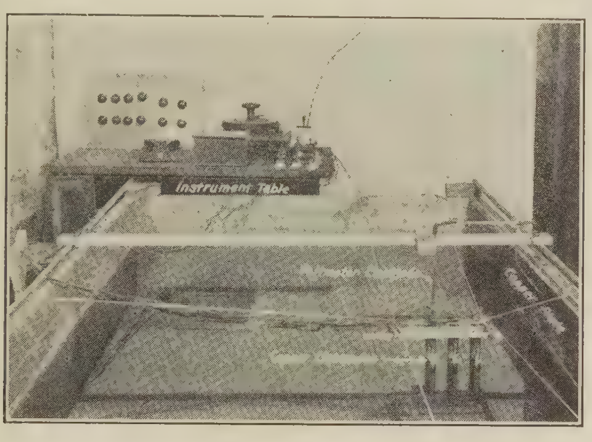

Fig. 4—Electrical Test Tank

The heat system is represented in the following manner. A unit length of the duct and its surrounding soil may be replaced by a rectangular wooden box containing ordinary tap water. (See Fig. 4.) Since the heat all flows to the surface of the earth, the ground surface may be replaced by a copper plate along one vertical side of the box, the remainder of the box being waxed to insure its insulating qualities.

A length of duct is represented by copper tubing set vertically in the water. The temperature difference between the cable and the earth's surface may be replaced by a d-c. voltage between the copper plate and the copper tubing, and the flow of electricity replaces the heat flow.

If the electrical system is constructed with the ratio of depth of electrode from the plate to radius of electrode which corresponds to the ratio of depth of duct to radius of duct, an electrode in one foot depth of water in the tank will completely represent a one-foot length of duct. If, then, a d-c. voltage is applied and the current measured, the electrical resistance of the system may be calculated.

By measuring the specific electrical resistance of the water in ohms per ft. cube, and dividing this into the resistance per unit depth of water, the electrical resistance coefficient (R/S), (ratio of resistance per unit length to specific resistance), may be found.

Now, since the flow of heat through the soil is governed by the same laws that govern the flow of electricity through the solution, and since the units of R/S are independent of system considered, the R/S for the heat system is exactly the same as the R/S for the equivalent electrical system. In this way it is possible to obtain an experimental check on the theoretical equations previously derived.

In running these tests it was necessary to take certain precautions to insure accurate results. In the first place, in order that the flow of electricity through the water would correspond to the flow of heat through the soil, it was necessary to limit the current density to such values that there would be no disturbing convection in the water due to heating and violent gassing at the electrodes. This limit was readily found by observation.

In the second place, it was necessary to devise some means of eliminating the error due to surface voltage drop between the electrodes and the water. This film resistance varies rapidly with changes in current density, gassing, and the condition of the surface of the electrode.

It was decided to measure voltage between the plate and a point 1/10 of an inch in a radial direction from the surface of the electrode under consideration, and compensate for this by considering the radius of the electrode to be 1/10 inch greater. Thus, all readings were independent of the surface voltage drop which varied from 2 to 10 volts depending on conditions. In this manner, an electrode 5/10 of an inch in diameter became 7/10 of an inch in diameter in the results.

The voltage was measured at 1/10 in. radially from the electrode by using a fine copper wire which protruded a short distance out of a small glass tube. The end of the tube was surrounded by a ring of 1/10 in. radius. Thus, when the ring on the rod was held in contact with the electrode surface, the copper wire voltmeter terminal was exactly 1/10 in. from the surface of the electrode. The fact that the voltmeter electrode projected only a short distance out of the glass tube made it possible to read the voltage at any depth in the water. In this way it was found that the flow was uniform at all depths for a given point.

Further investigation showed that the voltage readings given by a high-resistance voltmeter checked within one per cent of the readings given by a potentiometer, thus making it possible to speed up the work by using a high-resistance, direct-reading voltmeter instead of a potentiometer. A low-resistance voltmeter could not be used because the current drawn by it would be great enough to cause the exploring electrode to act as an auxiliary current electrode, thus distorting the flow.

As a final precaution, any electrical potential due to

battery action was eliminated by having no metal in the water except high grade copper. Any possibility of ground current through the box and floor was eliminated by using a generator and lines which were carefully insulated from the ground.

All specific electrical resistance measurements were made by means of a carefully calibrated bridge type Leeds-Northrop cell. Determinations were made at the beginning and end of each test, and at the temperature corresponding to the temperature of the water during the test.

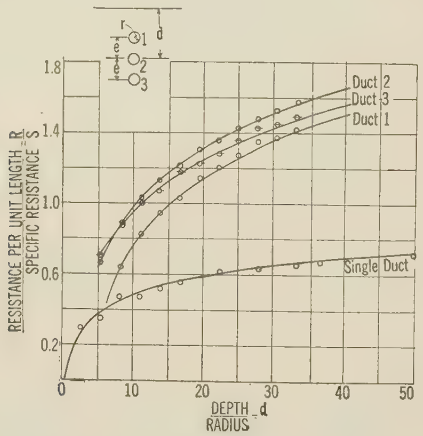

Fig. 5—Resistance Coefficient (R/S) for a Single Duct and for Three Ducts, Spaced Vertically as Shown for $l/r = 4$

Theoretical curves and experimental points shown

The electrical equivalent of one, three, and six ducts was set up and tested, and the values of a resistance coefficient R/S were found for various values of d/r.

Those experimental points are shown plotted in Fig. 5 and Fig. 6, together with the theoretical curves for the same conditions as derived in Appendix C. The experimental data are given in Appendix D.

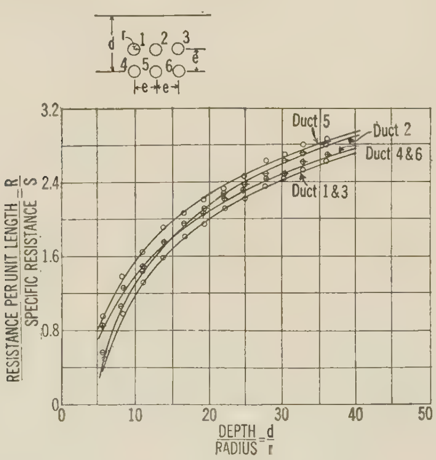

Fig. 6—Resistance Coefficient (R/S) for Six Cables Spaced Horizontally in Two Rows

Theoretical curves and experimental points shown for $l/r = 4$

As shown by the curves, the theoretical equations and experimental points check quite satisfactorily, showing that the distortion caused by close spacing of the electrodes does not cause appreciable error in the theoretical equations.

Conclusions

On the basis of the foregoing results, it does not seem unreasonable to state that the heat resistance of any one of a number of ducts may be calculated theoretically with confidence As stated earlier in the paper, the error involved in assuming that the ducts are buried directly in the soil is small and on the safe side, because the heat resistance of the concrete in which the ducts are set is less than that of most soils.

The fact that the cables lie in contact with the bottom of the ducts may cause the temperature of the bottoms of the ducts to be higher than that of the tops, and thus violate the assumption that the ducts are equi-temperature cylinders. It is difficult to believe, however, that this could cause serious distortion.

Throughout the discussion it has been assumed that the ground surface is an equitemperature plane. This is not strictly true, since it will be at a higher temperature directly over the duct than it is farther away. This effect is quite small except when the ducts are extremely close to the surface.

The expression for temperature of any duct of a group having different values of heat flow may be found by using a system of images in a manner exactly analogous to that used when the ducts dissipate the same amount of heat. However, the temperature of any one duct can be found only by knowing the heat flow from each duct, and the solution will be more involved.

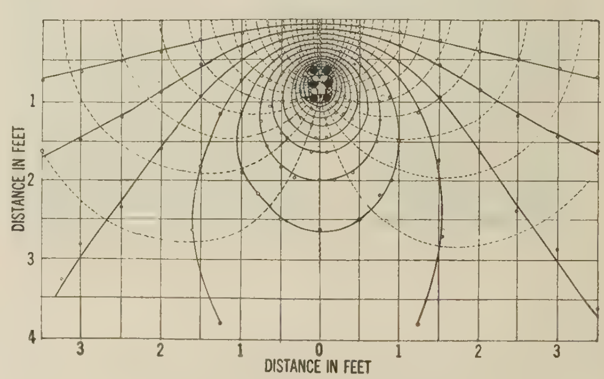

Fig. 7—Flow from Six Electrodes

Equivoltage surfaces—full lines
Lines of flow—dotted lines

Sufficient data exist to determine the specific heat resistance of most soils encountered so that it seems entirely justifiable to calculate the heat resistance for the ordinary arrangements of underground power cables by the theoretical method.

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Variable Speed Spinning of Cotton Yarn

BY E. A. UNTERSEE[1]

Synopsis.—*Variable speed drive for ring spinning frames, used in making yarns, has many advantages provided the driving mechanism has certain suitable characteristics. In this paper, the conditions which must be met are outlined, and it is shown that the most satisfactory method of drive is by means of the a-c., three-phase, shunt-characteristic, brush-shifting variable-speed motor.*

THE many advantages of varying the speed of the ring frames used in spinning yarns are well known to those who make these yarns. The problem in this connection has been to provide a driving mechanism which would allow the desired speed variation. In the past, various mechanical devices have been developed for this purpose, but all of these have proved unsatisfactory. The variable-speed electric motor is the only source of power which has been found to meet the required conditions, and in this case, also, considerable experience and development has been necessary before a motor with the proper characteristics was produced. This is the a-c. three-phase brush-shifting variable-speed motor having a shunt-motor characteristic.

Other types of motors were tried including (1) the wound-rotor induction motor with secondary-resistance control, (2) the d-c. adjustable-speed motor, (3) the multi-speed induction motor, and (4) the a-c. single-phase or three-phase, series, brush-shifting, variable speed motor. None of these adequately met all the requirements, both electrical and mechanical.

It would be well to examine the mechanical and electrical features of such a motor. The important mechanical features which such a motor for spinning yarn at variable speed should possess are enumerated as follows: 1. Enclosed construction; 2. Positive ventilation; 3. Minimum size; 4. Simple speed control mechanism; 5. Reversing mechanism; 6. Accessibility to working parts of motor.

In electrical performance the motor should have: 1. Good load speed characteristics. 2. Broad speed range. 3. Low temperature rise. 4. Good starting torque under all speed conditions. 5. High power factor and efficiency over entire speed range.

For the protection of the motor and operator, it is desirable to have an enclosed motor. While total enclosure is needed, even the temperature of the spinning room being a very important matter, space is also an important consideration, so that in order to avoid increasing its size unduly, the motor is best made enclosed but equipped to admit a supply of cool air and expel the heated air. The influence of heat and humidity upon the spinning process are known to be material, so that in certain cases the disposition of the heat resulting from the losses of the motor is of importance.

It may be desirable to expel the heated air outside of the spinning room and, on the other hand, in some cases it is thought to be of use in maintaining suitable room temperature in winter. To meet these different conditions, the motor should be enclosed and ventilated by means of built-in fans designed so that air can be taken in directly from the room (through screens) or through a duct from the outside; and that the heated air can be discharged either into the room, if beneficial, or into a duct to convey it away, if harmful. The cooling should be such that excessive radiation from external parts will not take place.

In order to obtain a minimum length of motor, ball-bearing construction is advisable. Direct connection to the cylinder of the spinning frame is a simple and satisfactory method of drive, but to have a flexible motor applicable to frames of various speeds and to either one cylinder or two cylinder frames driven by two motors and with cylinders too close together to allow of alining two direct-connected motors, the motor design should be such as to permit chain or gear drive as well as direct drive.

The speed control means should be such that the operator may disengage and reengage the automatic speed controller for a shut down and restart smoothly and easily.

The control device must be small and must be easily accessible and simple to adjust.

It is also desirable to have a motor whose direction of rotation can be easily reversed as it is frequently necessary to spin yarns of reverse twist.

The design of the motor must be such that any brushes, commutators, collectors, etc., which are to be used are easily accessible for inspection and maintenance.

Load speed characteristics of the motor are of very great importance. To obtain the maximum advantage of varying-speed spinning it is necessary to be able to repeat the cycle of speed variations against the position of the yarn or the bobbin as many times as is required and within rather small variations. It is also necessary to establish definitely whatever speed cycle of variations of speed is found best suited for the spinning in question.

The load of a spinning frame being in considerable part friction, varies considerably due to alinement of

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the frame, lubrication of spindles and other parts, and cleanliness, as well as tension on spindle bands or tapes. Further, the frame drives harder after a shut-down than when warmed up. There is a period of hard running when starting up each morning and after each noonday shut-down and a more severe period of hard running on Monday morning starts. These running conditions are intensified more in the winter than in summer months.

For these reasons a motor like the shunt brush-shifting whose speed is not seriously altered by moderate changes in load, is greatly to be desired.

From the above conditions it is apparent that any variation in speed which would of course be out of control, would introduce undesirable variations. Similarly, a variation in speed, due to heating up of the motor itself due to its periodic character could, to some extent, be controlled by periodic manipulation of the supply

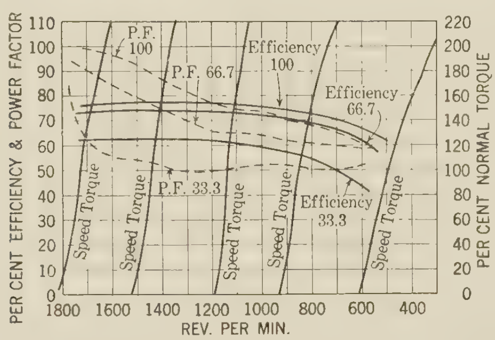

FIG. 1—CHARACTERISTICS OF THREE-PHASE, BRUSH-SHIFTING SHUNT-CHARACTERISTIC, MOTOR OF APPROXIMATELY 12½ HP.

The curve marked "Efficiency 100" shows the efficiency at 100 per cent of normal torque. Similarly "Efficiency 66.7 and "Efficiency 33.3" show efficiency at respectively 66.7 per cent and 33.3 per cent torque. Likewise "P. F. 100," "P. F. 66.7" and "P. F. 33.3" show power factor at 100, 66.7 and 33.3 per cent torque respectively

Curves marked "Speed torque" show relations at various brush positions

voltage, would still introduce complications which are objectionable.

When a frame is cold or stiff, it may require considerably more than normal running torque to break away, so that a liberal starting torque is very desirable in a motor. On the other hand, should there be a little slack in the yarn between the front rolls and the bobbin, with too abrupt a start, the ends of yarn will be broken. It is therefore of advantage and desirable to be able to vary the starting torque at the will of the operator to overcome the possibilities of end breakage.

The development of the a-c. three-phase brush-shifting *shunt-characteristic* motor in recent years has met with so much success in other lines of manufacture where it is necessary to maintain accurate speed regulation that it could not be overlooked for the spinning field. Experiments have been intensively carried on for the past four or five years with this type of variable-speed motor and results show that it meets the most exacting requirements in maintaining speed regulation which will allow constant tension on the yarn during the entire spinning process.

A short description of this type of motor, its operation and characteristics, is as follows:

This motor may be compared with the wound rotor induction motor having its primary winding in the rotor and its secondary on the stator. In addition, this machine has an adjusting winding in the rotor similar to a d-c. armature winding which is connected to a commutator. The motor is provided with two brush holder yokes arranged to shift in opposite directions.

One end of each phase of the stator (secondary) winding is connected to brushes on one brush yoke, and the opposite ends are connected to brushes on the other yoke. When the brushes, to which each end of a secondary phase is connected, are on the same commutator segment, the adjusting winding is idle, the secondary winding is short-circuited, and the motor runs as an induction motor with speed corresponding to the number of poles and frequency of supply. As the brushes are moved apart, a section of the adjusting winding is included in series with the secondary winding, causing the secondary winding to generate a voltage to balance the voltage impressed upon it by the adjusting winding, thereby causing the motor to change its speed.

With the brushes in low-speed position the motor gives from 140 to 250 per cent of normal torque at starting, with 125 to 175 per cent of full-speed current. The maximum torque at low speeds is from 140 to 250 per cent of normal torque and increases for the high-speed position to from 200 to 400 per cent normal torque.

The efficiency remains nearly constant over the greater part of the speed range, but drops some at the lower speeds. The average efficiency is high as compared with that of the wound rotor induction motor with secondary resistance or when compared with direct current motors with necessary alternating current direct current conversion apparatus.

The power factor is very high when the motor is running at high speeds. At synchronous speed, the power factor is similar to that of an induction motor of similar rating.

The decrease in speed from no-load to full load, at high speeds, is between 5 and 10 per cent, and at low speeds, slightly more according to the motor rating.

It may be operated in either direction of rotation by interchanging two of the line leads, as on an induction motor, and setting the brush rigging for the desired rotation.

Results of actual test made with this type of motor show between 10 per cent and 12 per cent greater production and better than 50 per cent less breakage of ends during the spinning process than are obtained with constant-speed drive.

Each number of yarn and quality of roving is subject to a definite speed curve which will permit maximum production and minimum breakage during the process.

It might also be stated here that the advantages of

variable speed for ring sprinning are not limited to cotton yarns but are quite as pronounced for worsted, wool and silk spinning.

Summing up the entire situation it may be said that when the proper speed curve has been obtained for any given yarn the resultant advantages from the use of such a variable-speed motor will be: 1. Maximum production of yarn; 2. Better quality yarn; 3. More uniformly wound bobbins; 4. Increased yardage; 5. Minimum breakage of ends; 6. More of the operator's time available for cleaning machine and other duties.

Abridgment of

The Gould Street Generating Station of the Consolidated Gas, Electric Light and Power Company

BY A. S. LOIZEAUX[1]

Associate, A. I. E. E.

Synopsis.—*The paper is descriptive of the Gould St. Plant. Pulverized coal is prepared in a separate building. Only one boiler is provided per turbine, each boiler delivering a maximum of 520,000 lb. of steam per hour. Automatic control is provided for the electric drive of boiler auxiliaries, electric auxiliaries being used throughout the plant; a 250-volt exciter and 460-volt house turbine are on main generator shaft. Switch house is of isolated phase construction with vertical operation of switches. Actual costs are given for the first unit, with estimated costs for completed plant, resulting in costs for the completed plant of $88 per kw. for normal output and $80 per kw. for maximum output.*

* * * * *

THE new Gould Street Plant which began operation in January, 1927, is located in the City of Baltimore on the Patapsco River, an arm of the Chesapeake Bay. This water front site was formerly the power plant location of the Baltimore Electric Company which had been purchased by the Consolidated Company in 1908, and has not been in operation since 1918. The comparison between the old plant and the new illustrates the great advance in the art of electric power generation during a period of 20 years, the new units having twelve times the capacity of the old, with a coal rate of the new plant less than one-half that of the old plant.

From the standpoint of nearness to important load centers the site is highly desirable so that the energy is distributed by underground cable at 13,200 volts without transformation. The plot measures 405 ft. by 635 ft. and is of sufficient size to supply load growth for perhaps 10 years, when the progress of the art of power generation will probably make it desirable to begin anew in another location with higher pressures, higher temperatures, and, perhaps, a materially different heat cycle.

Sources of Power in Baltimore

The accompanying map, Fig. 1, shows the territory served by the Baltimore plants and indicates the city limits and the location of the Westport and Gould St. plants; also the former railways plant at Pratt St.

The Westport plant began operation in 1905 and provided for growth of load through 1926, a period of 21 years. Westport has a 25-cycle capacity of 125,000 kw. and 60-cycle capacity of 40,000 kw.

The Pratt St. plant was formerly a railway generating station but now contains only one standby unit of 20,000-kw. capacity.

Hydro Energy

A considerable part of the electric energy used in

Fig. 1—Territory Served by the Consolidated Gas, Electric Light & Power Co. System

Baltimore comes from the Holtwood plant of the Pennsylvania Water and Power Co. The Holtwood plant is located on the Susquehanna River at Holtwood, Pennsylvania and consists of a hydroelectric plant with 87,000 kw. in 25-cycle capacity and 24,000 kw. in 60-cycle capacity. There is also a steam station at Holtwood of 25,000-kw., 60-cycle capacity. The transmission lines from Holtwood to Baltimore are 25-cycle, 66,000-volt; 40 mi. long.

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Presented at the Regional Meeting of the A. I. E. E., District No. 2, Baltimore, Md., April 17-19, 1928. Complete copies upon request.

Gould Street Generating Capacity

Gould St. has one 36,000-kw. unit operating and a second duplicate unit which will begin operation in April, 1928. The plant is designed for four 36,000-kw. units, a total of 144,000 kw. at 60 cycles.

Arrangement of Plant

The general view in Fig. 2 shows the arrangement of the plant, the power house being built on the water's edge. The coal unloading tower is placed about the center of the bulkhead line. Coal is transported by belts to the pulverizing plant. The buildings of the former generating plant were used, the old boiler house being transformed into a pulverizing plant and the old turbine room into a service building and machine shop. The switch house is a new building on the north end of the property toward the city, the power station and switch house being connected by underground concrete tunnels.

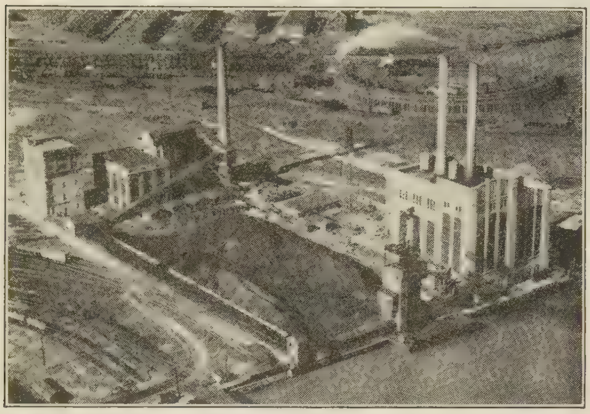

Fig. 2—Aerial View of Generating Station

Cross-Section of Power House

Fig. 6 is a cross-section of the power house, showing a rather compact arrangement of equipment, yet providing ample space for operation. Abundant natural light and ventilation is provided for both turbine room and boiler room. A pipe gallery provides for longitudinal runs of pipes. The electrical gallery is open to the turbine room and on the same level as the turbine floor giving easy access to electrical operation.

Coal Feeders

The coal is fed by four quadruplex screw feeders per boiler to sixteen Lopulco type burners through 6-in. pipes crisscrossed to prevent stratification in the furnace in the event of outage of one or more feeder groups.

Furnace

Three sides of the furnace are water-cooled by fintube surface backed by special tile, rock wool insulation and steel casing. The front wall is of firebrick, cooled by the preheated secondary air, admitted to the furnace through ports at 16 levels in this wall. A water screen interconnected with the rear wall circulating system protects the inclined floor of the furnace which forms the ash hopper.

Air Supply and Gas Removal

Primary air, used to convey powdered fuel from the screw feeders to the burners, is a mixture of preheated air tapped from the secondary duct and tempered with room air. Primary air is supplied by two fans per boiler, connected on the discharge by an air bus, which makes any fan available for either boiler. Two forced draft fans per boiler furnish the secondary air taken from the room and discharged into a plenum chamber directly ahead of a C-type plate preheater mounted above the gas outlet of the boiler.

Tertiary air is taken from the secondary air duct for admission around the burners.

The gases leaving the preheater are removed by two induced draft fans and discharged into an eleven-ft. diameter self-supporting unlined steel stack, one per boiler, extending 213 ft. above the burner arch.

Boiler

The use of one boiler for a 36,000-kw. turbine with only one additional boiler as a spare unit marks an advance in plant design. Each steam generating unit has a maximum output of 520,000 lb. per hour at 450-lb. drum pressure and 725 deg. fahr. superheater outlet temperature, which is sufficient for about 46,000 kw. turbine capacity. Reserve capacity gained by increased size of boiler auxiliaries even at some sacrifice in normal operating economy, was found to be more economical than the addition of spare boiler units. Four turbines will ultimately be supplied by five boilers. Fig. 7 is a section of boiler and furnace.

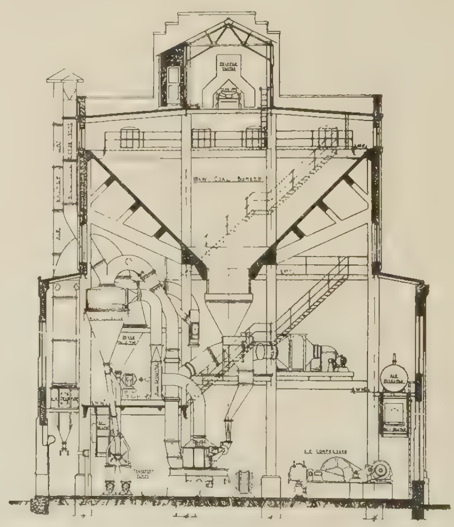

Fig. 5—Cross-Section of Coal Preparation Plant

Several features in the design of the boiler, a conventional B & W cross-drum steel encased type, were unique. It was the first boiler at 450 lb. pressure to have 4-in. tubes. A considerable increase in heating surface was gained at small expense by extension of

tube length from 22 ft. to 24 ft. Modifications in the manufacturer's previous design allowed an advance from 385 lb. to 450 lb. operating pressure. The drum diameter, 60-in., was the largest attempted for that pressure at that time, and the length of 34 ft. was the greatest that the manufacturer could furnish without a girth seam. Two steam outlets were insisted factor, 1876-rev. per min., 13,200-volt, three-phase, 62½-cycle machine, which is designed to operate later at 60 cycles. In addition to the main generator there is a shunt-wound shaft exciter rated at 250 kw., 250 volts d-c. overhung on the main shaft and beyond this and connected by means of a Fast flexible coupling is an auxiliary generator having a capacity of 1500 kv-a.

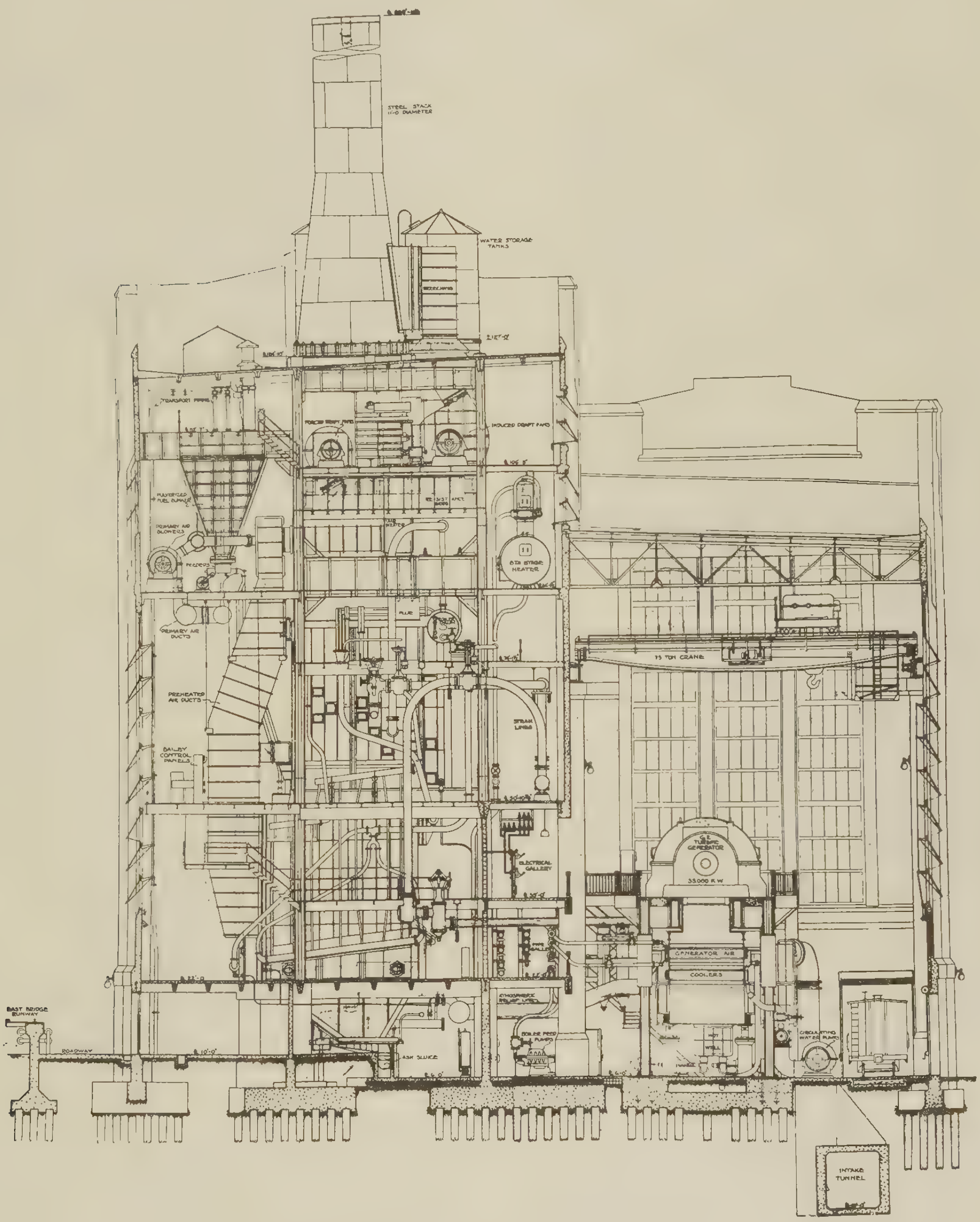

Fig. 6—Cross-Section of Turbine Room and Boiler House

upon. General Electric steam flow meters, modified for use as water level indicators and recorders, are installed at the operating floor level.

Turbo-Generator

Fig. 8 gives a view of No. 1 unit in the foreground, and unit No. 2, under construction, in the background. The alternator is a 43,750-kv-a., 80 per cent power at 80 per cent power factor and 460 volts, three-phase, 62½ cycles. The over-all length of the turbo-generator unit is 69 ft.

The turbine is a 13-stage Rateau impulse machine of 36,000-kw. capacity and drives the main generator through a Fast flexible coupling. It is a modified form of a turbine of lower normal rating of the non-bleeding type. The initial stages, however, have been opened

up to pass the additional steam used in bleeding. Steam is supplied at a normal pressure of 390 lb., and a total temperature of 700 deg. fahr. Steam is bled at the 3d, 5th, 8th, and 10th stages at full-load pressures of 193, 99, 30, and 9 lb. absolute, respectively. The turbine is designed for highest efficiency at 25,000 kw.

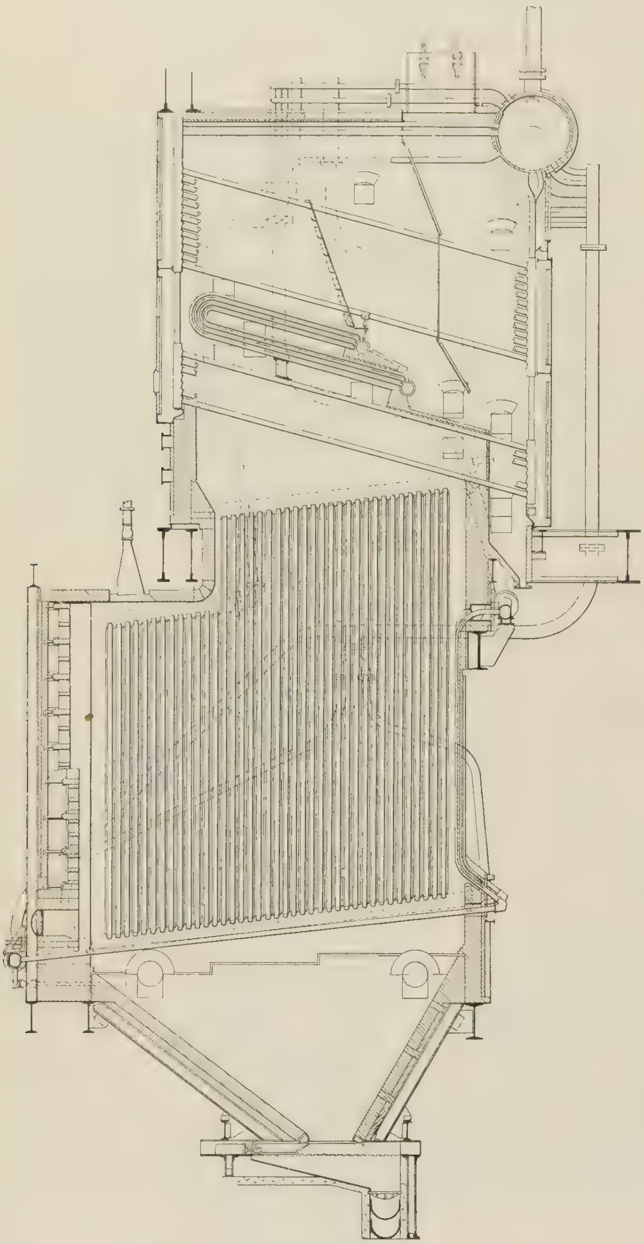

Fig. 7—Cross-Section of Boiler and Furnace

load, and when bleeding steam at four points, the unit can produce a net station send-out of 36,000 kw., which is the company rating of the machine. A considerably larger output can be produced by bleeding at the two lower points only.

Condenser

A 30,000-sq. ft. two-pass condenser is bolted directly to the bottom of the turbine exhaust casing, and is supported partly by the casing and partly by springs on structural piers on the basement floor. The circulating water passages are so arranged that the cooler water leaving the air devaporizing and cooling section is returned in the second pass in the annular ring of tubes around the outside of the top section with which the

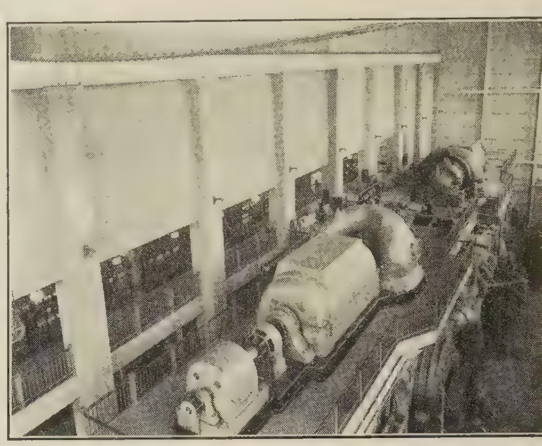

Fig. 8—View of Turbine Room showing No. 1 and No. 2 Units

exhaust steam first comes in contact. The shell is eccentric with the tube sheet, providing a steam belt which, on one side, extends to the hot well, preventing excessive condensate depression.

The tubes are rolled into both tube sheets, a new feature of design that is discussed in other papers.

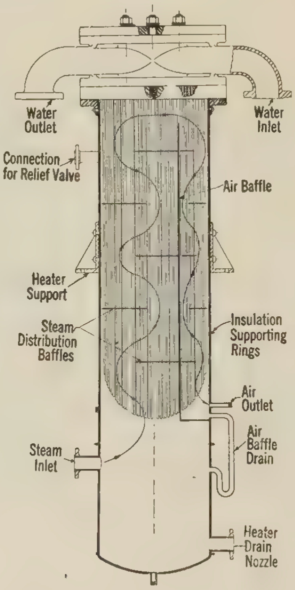

Fig. 9—Bleeder Heater of Hair-Pin Loop Construction

Bleeder Heaters

The 3d-, 5th-, and 10th stage bleeder heaters, the evaporator condenser, and the after condenser, are of the vertical, closed type with four passes each. The construction of these heaters is shown in Fig. 9. The tube surface is made up of ¾-in. outside diameter. No. 14-gage Admiralty tubing, which is bent into hair-pin loops with both ends rolled into a single-tube sheet.

The shells are of steel with hammer welded joints. Water boxes on the high-pressure heaters for the first unit are of cast steel, but on the second unit will be of rolled plate. Steam is introduced in each case below the tubes and the baffles are arranged so that a vapor cooling chamber is provided to which the air vent connection is made at the side of the shell.

The 8th-stage heater is of direct-contact deaerating type in which part f the bled steam is used in a section into which the condensate is sprayed through jets and part is used in another section similar to the open type feed heater in which trays are located and from which the air is removed. The pressure in the heater varies as the bled steam pressure varies. This heater is in the boiler house at an elevation of 80 ft. above the boiler feed pumps, which take their water from it. With a shell capacity of 6400 gal. it serves as a closed surge tank. The only condensate in the cycle which comes in contact with air is the condensed drip in the after condenser, which passes through the deaerating heater on its way back to the boiler.

Investment Costs per Kw. Capacity

Throughout the design of the Gould St. Plant the object was to secure maximum reliability with minimum total costs per kw-hr. By total costs is meant not only operating labor and superintendence, maintenance, and fuel cost, but fixed charges on the investment. This criterion was used in the choice of apparatus, the cost of the apparatus being weighed against its ability to reduce production costs.

We give below a table of the actual cost of the first unit, and the estimated costs of three additional units; the estimated cost of the completed plant of 144,000 kw. being $88.26 per kw.

	One unit (Actual)	Two units (Est.)	Three units (Est.)	Four units (Est.)
1. Investment cost as per Report of June 20, 1927..	$4,681,821	$7,396,224	$10,090,322	$12,709,909
2. Capacity—kw...	36,000	72,000	108,000	144,000
3. Cost per kw.....	$130.05	$102.73	$93.43	$88.26

The wide spread between the cost per kw. of the first unit and the cost per kw. of the completed plant is due to the many items included under the first unit, which are designed for the completed plant, such as, land, relieving platform for coal storage, coal handling, preparation plant, etc.

The capacities given in the above table are the net send-out capacity with four-stage bleeding.

Under two-stage bleeding conditions capacity is increased considerably and a net send-out capacity of 40,000 kw. is readily obtained and will be obtained in the event of need, for peak load conditions. Figuring this higher capacity the investment costs become as ollows:

	One unit (Actual)	Two units (Est.)	Three units (Est.)	Four units (Est.)
1. Investment cost as per report of June 20, 1927..	$4,681,821	$7,396,224	$10,090,322	$12,709,909
2. Capacity—kw...	40,000	80,000	120,000	160,000
3. Cost per kw.....	$117.05	$92.45	$84.08	$79.44

The investment figures given include all expenses of every nature in connection with this plant, covering such items as preliminary engineering, old buildings used, interest during construction and during tuning up period, also a portion of the floating equipment of the company properly allocated to serve this plant.

HIGH-VOLTAGE RESEARCH IN INDIA

Considerable activity in high-voltage research has been shown recently in India, and some of the interesting results obtained have come to the attention of the Institute.

The report of some recent experimental work describes a study of a-c. corona by G. Yoganandam and S. K. Gopinath of the Indian Institute of Science, Bangalore, India. The wave forms of the corona current from a wire in a cylinder and from a wire in front of a plane were obtained with an ordinary oscillograph, the currents being amplified for this purpose by means of a special vacuum-tube circuit. The waves secured were analyzed and show a considerable number of harmonics. The corona wave forms were, however, much smoother than those obtained by Bennett.[1] Assuming both halves of the current wave to be alike, an equation for space charge current was derived, separate from that of the capacity current.

A set-up similar to that used by other investigators in this country,[2,3] in which the charge from a wire to a ground mesh is pulled through the latter by means of a polarized plate, with a galvanometer in the circuit of the plate indicating the flow of charge drawn in, was also employed. In this way, they were able to study approximately the amount of charge reaching ground and also the rectifying effect present. The results here, for the most part, checked the previous work of others,[2,3] but, in addition, showed an interesting frequency effect to be present. The critical corona voltages for positive and negative corona were found to be slightly lower for 25 cycles than for 60 cycles. The space charge reaching the ground plane was also higher for 25 cycles than for 60 cycles.

In addition to the above, the Indian research workers have carried out considerable work in insulator-string testing and the measurement of the voltage distributions over them. Several interesting methods were used in this, and have been described in articles by G. Yoganandam and R. K. Sen (*Journal* Indian Inst. of Science 1927, Bangalore, India V. 10B, Part II, pp. 21-33 and Part IV, pp. 43-49).

1. E. Bennett, Trans. A. I. E. E., 1913.
2. C. H. Willis, Trans. A. I. E. E., 1927.
3. Carroll and Lusignan, Trans. A. I. E. E., 1928.

Lichtenberg Figures

BY C. EDWARD MAGNUSSON[1]

Fellow, A. I. E. E.

IN 1777, one hundred and fifty-one years ago, Dr. George Christoph Lichtenberg, Professor of Physics in the University of Göttingen, observed that under certain conditions an electric discharge produced curious and strangely beautiful figures. Lichtenberg's apparatus and circuit arrangement were very simple and can readily be reproduced. Place a pane of glass on a metal plate connected through a spark-gap to the outside coating of a Leyden jar. Connect the tinfoil on the inside of the jar to a metallic electrode, touching the upper surface of the glass plate. When the Leyden jar is discharged, figures are produced on the glass surface around the point of contact of the electrode. These figures may be made visible by sifting some light powder, (such as lycopodium), over the glass surface. By using flower of sulphur and finely powdered red lead, or other colored powders, the different shapes of the negative and positive figures may be shown in an impressive manner. With the discovery of photography almost a century after Lichtenberg's day, a much more convenient method was obtained for visualizing the phenomena. In 1888, J. Brown and E. T. Trouvelet found that figures similar to those obtained by Lichtenberg could be obtained photographically by replacing the glass or rubber plate with a photographic plate; the emulsion side being placed in contact with the electrode. On developing the exposed plate, very beautiful figures were obtained. As the photographic plate makes a permanent record greatly superior to the dust figures, the latter are seldom used, and the photographic records are generally referred to as *Lichtenberg Figures* although *photographic Lichtenberg figures* would be more specific. (To give a general view of the phenomena discussed, a number of typical positive and negative Lichtenberg figures for various forms of impressed electric surges or impulses were shown on the screen. The true Lichtenberg figures were differentiated from figures produced by brush discharges and glide sparks.)

Although Lichtenberg figures have long been recognized as of scientific interest and are frequently used in lecture room demonstrations, until recently, no practical application had been found. It was not until 1924, when J. F. Peters of the Westinghouse Electric & Mfg. Company published the results of his work on the development of the klydonograph that the importance of Lichtenberg's discovery was appreciated by engineers. This instrument, by means of Lichtenberg figures, records voltage impulses, whether of extremely short, or of longer duration, thus producing permanent graphic records that give information as to polarity, magnitude, wave-front, etc., of electric surges and impulses in electric circuits. The surge voltage recorder, developed by the General Electric Company is a modified form of the klydonograph which gives simultaneous records of both the positive and negative Lichtenberg figures. (Circuit diagrams of klydonograph and surge voltage recorder were shown on the screen.)

It should be noted that the interpretation of Lichtenberg figures as obtained by klydonographs and surge voltage recorders is largely dependent on an accessory instrument, the cathode ray oscillograph, recently developed by Professor Dufour. (The speaker digressed to give a brief outline of the Dufour type of cathode ray oscillograph and stressed its importance in analysing Lichtenberg figures and in the direct study of lightning phenomena and other electric surges and high-speed impulses.)

Extended investigations have been made in past years on Lichtenberg figures by a number of distinguished physicists, notably Toepler, Pedersen, Przibram Oshida and others and many facts and relations of the physical factor involved have been established and recorded in scientific journals. After the invention of the klydonograph by Peters, many important advances both as to the nature of the figures and their application to the study of electric surges and impulses have been made by American engineers notably McEachron, Wade, Lee, Foust, Cox, Legg, and their associates. The more important known relations may be noted, as follows:

a. The positive and negative figures differ in shape and appearance for the same voltage impulse.

b. The size of the positive figure is larger than the negative figure for the same impressed voltage.

c. The radius of the figure is a linear function of the voltage. The size of the figure depends to some extent on the thickness of the dielectric between the sensitized emulsion film and the metal plate so that instruments like klydonographs and surge-recorders, based on Lichtenberg figures, must be calibrated. In general, the relation of impressed voltage E in kilovolts and the radius R of the figure in centimeters (radial distance from metal pole to circumference of figure) is expressed by equations (**1**) and (**2**).

$$E = 11.5\,R \text{ (approximately) for negative figures} \quad (1)$$

$$E = 5.9\,R \text{ (approximately) for positive figures} \quad (2)$$

d. The steepness of the wave-front affects the shape and appearance of the positive figure.

e. The form of the figure indicates whether the impulse was unidirectional or oscillatory.

1. Dean, College of Engineering, Univ. of Washington.

Lecture delivered at the Pacific Coast Convention of the A. I. E. E., Spokane, Washington, August 28-31, 1928. (Printed complete herein.)

f. The speed of formation of the positive figure is in the order of 10^7 cm. per sec.

g. A practical application was made by Pedersen (1919) in devising an ingenious circuit arrangement whereby Lichtenberg figures may be used as a means for measuring short intervals of time—in the order of 10^{-7} second. This method has been used for determining the time lag of spark-gaps.

h. The application of Lichtenberg figures for producing permanent records of electric surges and impulses by the invention and development of the klydonograph, surge voltage recorder, etc.

Many other relations have been studied, such as the effects produced by the shape of the electrode, variations in air pressure, moisture in the air, the probable flow of electrons and ions, material and thickness of the dielectric, material and shape of spark-gap, etc., but comparatively little work of a conclusive nature has been done to determine the physical mechanism existing between the electric impulse in the circuit and the figure formed on the photographic plate.

During the past two years, work toward solution for the problems stated below has been in progress and this lecture will, in the main, deal with the results already gained, as well as the experiments in progress at the University of Washington:

a. Are Lichtenberg figures formed by the motion of electrons, by positive and negative ions, or by other means?

b. Is the action on the photographic plate produced directly by the same mechanism that causes the dust figure in Lichtenberg's original experiment or is the photographic action caused by light, an additional link in the chain of events? It is evident that in Lichtenberg's original experiments the light factor did not enter into the formation of the figure while the natural presumption is that in the formation of the record on the photographic plate, light will be the immediate cause.

c. To what extent, if any, is the photographic record dependent upon the kind of sensitized plate used?

d. What effect has the air pressure on the form and size of the negative as well as the positive figures?

e. Is the form of the figure dependent on the duration and form of the electric impulse?

Belt Generator. In planning this work, the first difficulty that had to be overcome was to obtain a convenient and dependable but inexpensive source of high-voltage impulses having very steep wave-fronts. For this purpose, the "static" from a belt, driving a generator in the laboratory, proved satisfactory. For convenience a two-ply, leather belt, 10 in. by 26 ft., was arranged to run on idler pulleys (one metal and one paper) as a high-voltage *belt generator*. This simple machine, at a belt speed of 4900 ft. per min., proved an excellent source of steep wave-front impulses (a fraction of a microsecond) up to 100,000 volts in magnitude. All the Lichtenberg figures shown in this lecture were made from impulses produced by the belt generator.

Photographic Plates. In order to secure the best records, it seemed advisable to look into the relative merits of the readily available types of photographic plates for making Lichtenberg figures. For this purpose, two surge recorders were placed in a divided circuit of which the two branches were of equal length. By using plates of different makes in the two instruments, it was possible to determine the merits of the plates by comparing the two figures produced simultaneously by the same electric impulse. The Eastman Speedway plate was used as a basis for comparing the intensity and quality of the figures found on the following types of photographic plates and films: 1. Eastman 40 plate; 2. Eastman Orthochromatic plate; 3. Eastman Panchromatic plate; 4. Eastman Speedway plate; 5. Eastman Universal plate; 6. Eastman Kodak film; 7. Eastman Process film; 8. Hammer (extra fast) plate; 9. Ilford Iso Zenith plate; 10. Lumière Sigma plate.

The clearest and best figures were obtained on the Lumière Sigma plates with Speedway plates in second place. As a consequence of this test the Lumière Sigma plates have been used in this work; with the exception that for a short period when the Sigma plates were not available the Eastman Speedway plates were used. (Slides showing simultaneous records of the several types of plates.)

Electrons or Ions Forming Positive and Negative Figures. If it be assumed that an electric impulse or current consists of a directional flow of electrons, protons or ions carrying positive and negative charges, one or more of these groups must be present and form at least a link in the mechanism that produces Lichtenberg figures on the photographic plate. As the figures under discussion are formed without the presence of hydrogen, protons, as such, need not be considered.

Since the mobility of the electron is very much greater than that of positively or negatively charged ions and the speed of formation of the figures is of the same order as the mobility of the electrons it seems highly probable that the first stage in the formation of both the positive and the negative figures is a sudden wave of electrons moving at great speed over the surface of the plate. The difference in shape and size of the positive as compared to the corresponding negative figure can be accounted for by assuming that the direction of flow of the electrons is in opposite directions with respect to the two electrodes. This can best be shown by referring to the circuit diagram in Fig. 2 and to the corresponding negative and positive Lichtenberg figures in Figs. 3 and 4.

The diagram in Fig. 2 shows two photographic plates, placed back to back, with a sheet of black paper (to prevent light from affecting more than one plate) and alcohol (to exclude the air) between them. The negative electrode rests on the emulsion surface of the

top plate while the emulsion side of the lower plate is in contact with the positive electrode. Let an electric impulse come from the negatively charged air of the belt generator as evidenced by a spark across the spark-gap. This means that a stream of electrons pass from

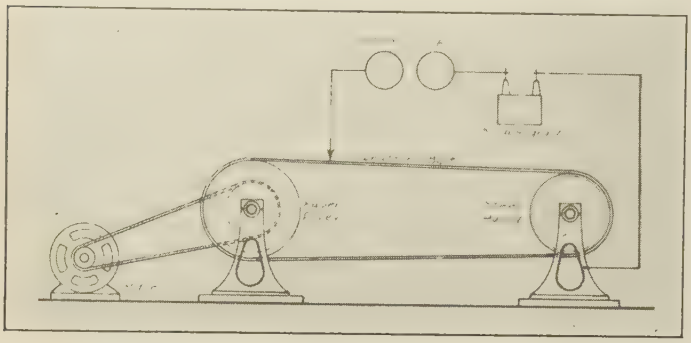

Fig. 1—Belt Generator, 100,000 Volts

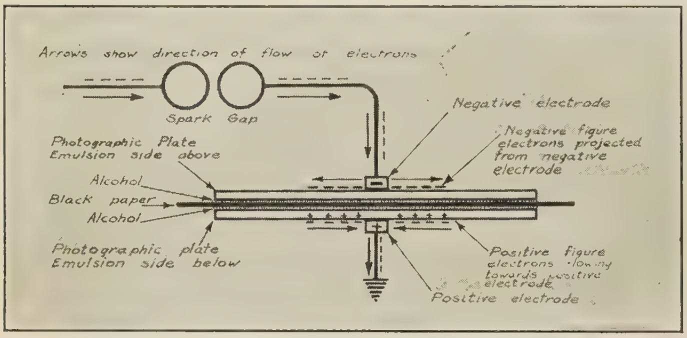

Fig. 2—Circuit Diagram Showing Two Plates in Series for Taking Negative and Positive Figures Simultaneously as Shown in Figs. 3 and 4

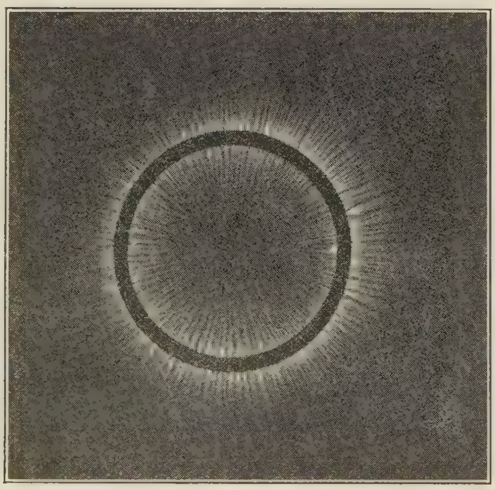

Fig. 3—Negative Figure. Upper Plate, with Circuit as in Fig. 2

the spark-gap to the negative electrode. With sufficiently high-voltage gradient these electrons are projected out from the negative electrode over the plate surface. By induction, a like number of positive charges will be held on the emulsion surface of the lower plate by the electrons on the upper plate, thereby releasing a corresponding number of electrons on the under surface of the lower plate. These electrons, carrying negative charges, are attracted by the positive electrode, and if sufficient voltage gradient exists, they flow into it and pass to ground.

It should be noted that in both cases, the direction of motion of the voltage gradient wave is from the electrode, radially outwards, that the electrons on the

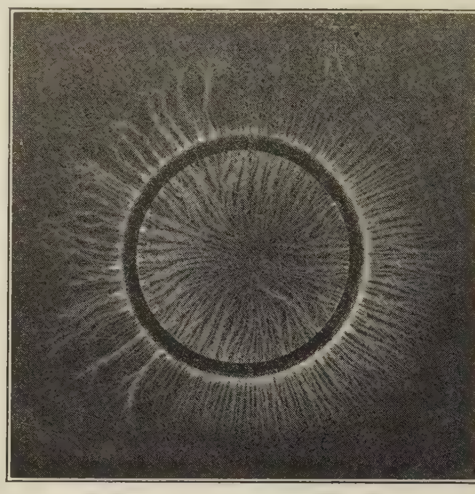

Fig. 4—Positive Figures. Lower Plate, with Circuit as in Fig. 2

Fig. 5—Conical Electrode, Point Contact—Positive Figure

upper plate—negative electrode—are projected outwards away from the electrode, while simultaneously on the lower plate, the electrons are attracted by and move towards the positive electrode.

In Figs. 5 to 13 inclusive are shown positive and negative figures produced with point, circular, and ring electrode contacts on the photographic plates. An examination of these photographs will support the proposition that the process of formation for the negative figure is based upon projection of electrons

away from the negative electrode, while for the positive figure, it is based upon electrons flowing towards the positive electrode. Because of the irregularities of the electrode surface, there will not be uniform emission at all points on the circumference, but a number of starting points are formed from which streams of

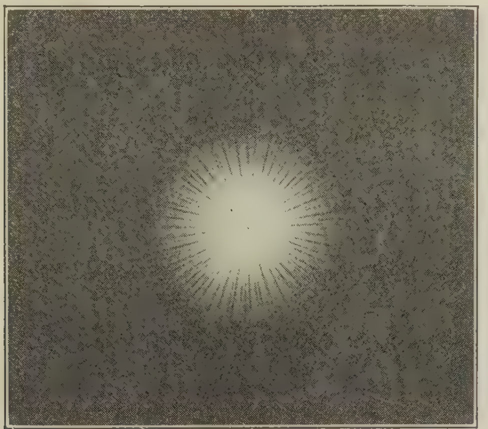

Fig. 6—Conical Electrode, Point Contact—Negative Figure

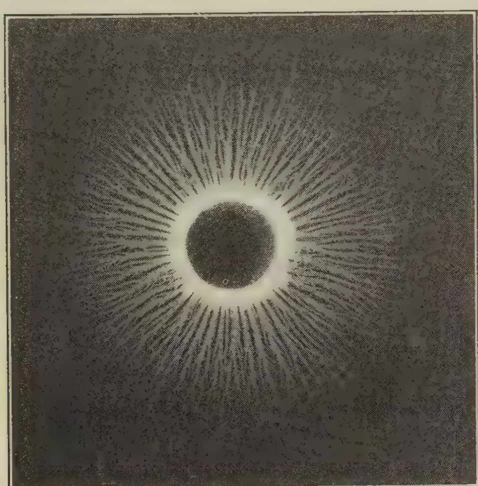

Fig. 7—Cylindrical Electrode, Circular Contact—Positive Figure

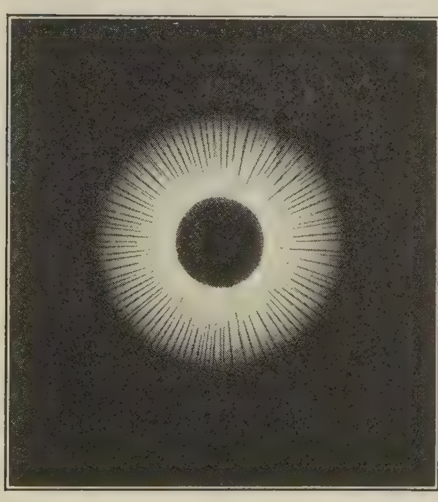

Fig. 8—Cylindrical Electrode, Circular Contact—Negative Figure

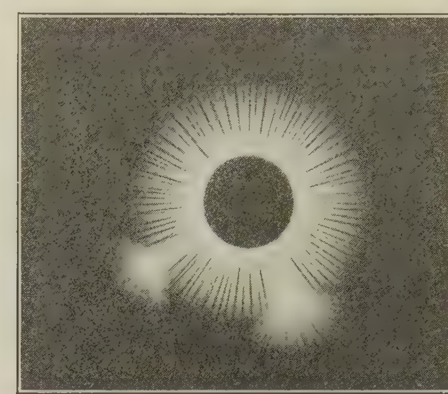

Fig. 9—Cylindrical Electrode, Circular Contact—Negative Figure

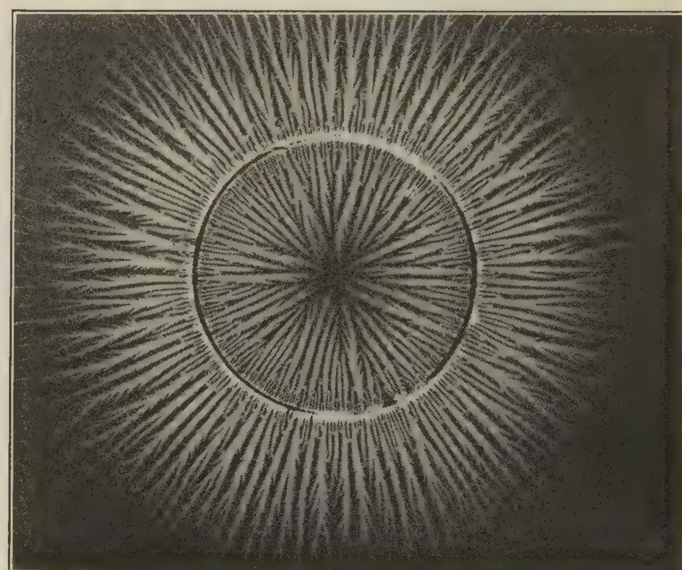

Fig. 10—Tubular Electrode, Ring Contact—Positive Figure

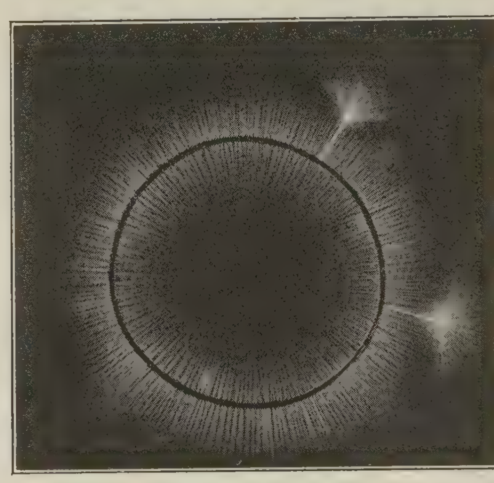

Fig. 11—Tubular Electrode, Ring Contact—Negative Figure

mutually repelling units are projected. In Figs. 9 and 11 the voltage was sufficient to project two groups of electrons along well defined grooves beyond the circumference of the normal figure. At the end of these grooves, the projected electrons spread out in a fan-like form caused by the mutual repulsion existing

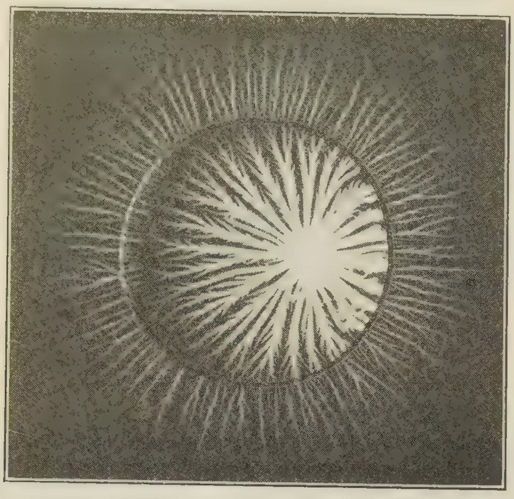

Fig. 12—Electrode Making Point Contact Inside of Ring in Contact with Plate—Positive Figure

between charges of the same sign. The formation of grooves or narrow paths offering less resistance to the flow of electrons is shown to good advantage in Figs. 12 and 13 in which the electrode has a point contact with the plate inside of a metal ring resting on the plate but not metallically connected to the electrode.

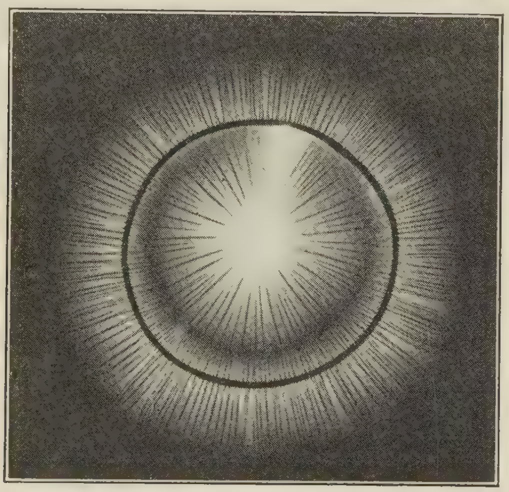

Fig. 13—Electrode Making Point Contact Inside of Ring in Contact with Plate—Negative Figure

Light as a Factor in Forming Lichtenberg Figures. It seems evident that in Lichtenberg's original experiments the light factor, even if present, had no direct bearing on the formation of the figures. A flicker of light appears around the electrodes when the electric impulse producing Lichtenberg figures passes through the circuit. To determine whether or not the light appearing at the electrode is a factor in the formation of the photographic record of Lichtenberg figures, the following experiments were made:

A photographic plate with the emulsion side up was placed in a klydonograph in the usual manner. A clear pane of glass was placed on top of the photographic plate and the space in between filled with alcohol to exclude the air. A spark in the klydonograph circuit produced a Lichtenberg figure on the photographic

Fig. 14—Surface Partly Covered by Nujol Oil —Positive Figure

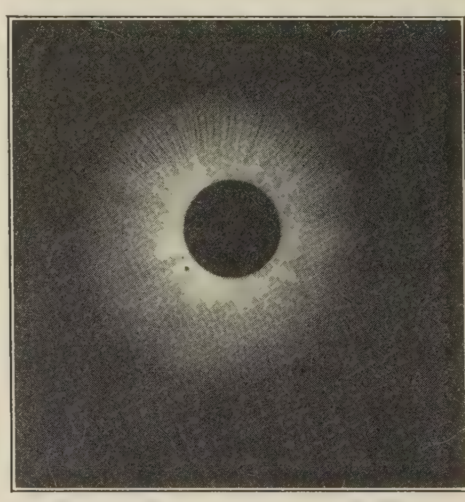

Fig. 15—Surface Partly Covered by Nujol Oil —Negative Figure

plate but the outline of the branches in the positive figures were hazy and indistinct. This, naturally, would be the case, as the electrons had to move necessarily on top of the cover plate; hence, the light would disperse before reaching the emulsion on the photographic plate. After inserting a thin black paper, opaque to light, between the cover plate and the photographic plate but otherwise, the same circuit arrangement as above,

a second exposure was made. In this case, no Lichtenberg figure appeared on the photographic plate.

A second method for solving the problem was devised. The klydonograph was loaded with a photographic plate, emulsion side up, and a few drops of Nujol oil was placed at the point of contact of the electrode. Typical examples of Lichtenberg figures found by this

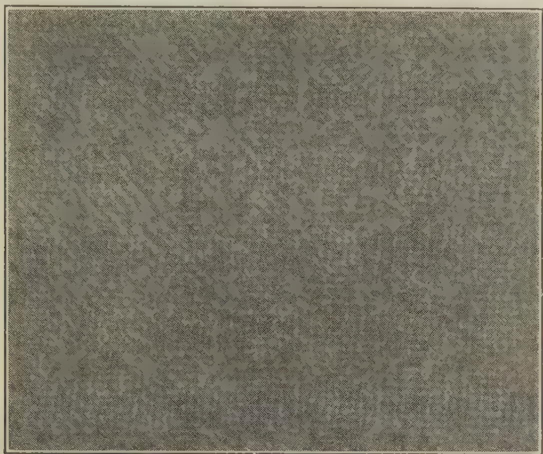

Fig. 16—Reproduction of a Micro-Photograph of Prong in Positive Figure (1000 Diameters)

method are shown in Figs. 14 and 15. It should be noted that the figures are sharply "focused" in the areas not covered by the oil, but hazy where the plate was covered by oil. This would follow if the formation of the light occurs on the surface of the oil and on the bare parts of the plate; namely at the surface boundary between the air and plate or air and oil.

From the experiments using a cover plate, as well as

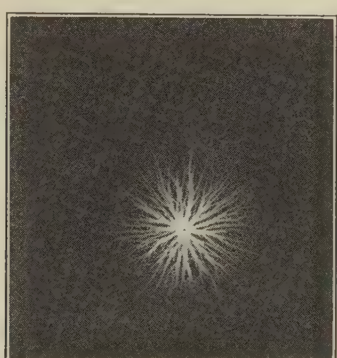

Fig. 17—Positive Figure. Pressure 76 cm.

from the results gained by using Nujol oil, it became evident that the light factor is the immediate agent in forming the photographic record of Lichtenberg figures. The sharpness of the images in the places not covered by the oil, and of the figures taken without any covering, may be considered as well nigh conclusive evidence for the assumption that the source of the light that produces the photographic record in Lichtenberg figures is found in an exceedingly thin layer directly on the surface of the photographic plate; that is, essentially in the surface boundary between the air and the emulsion film. It appears probable that the thickness of the surface layer traversed by the light producing electrons is a function of the wave-front of the electric impulse. (Figures taken through cover glass and also with surface partly covered by Nujol oil were shown on screen.)

Micro-Photographs. To gain more evidence as to the effect of the light factor in the formation of Lichtenberg figures micro-photographs (magnification 1000 diameters) were taken of the prongs and "in between spaces" of the positive figures. In Fig. 16 is shown a typical micro-photograph of a slender prong—the heavily spotted band across the figure—of a positive figure. The sharpness of the edges compares quite favorably with what is found in sharply focused photographs. The density of the black specks between the prongs of the figure is approximately the same as in the

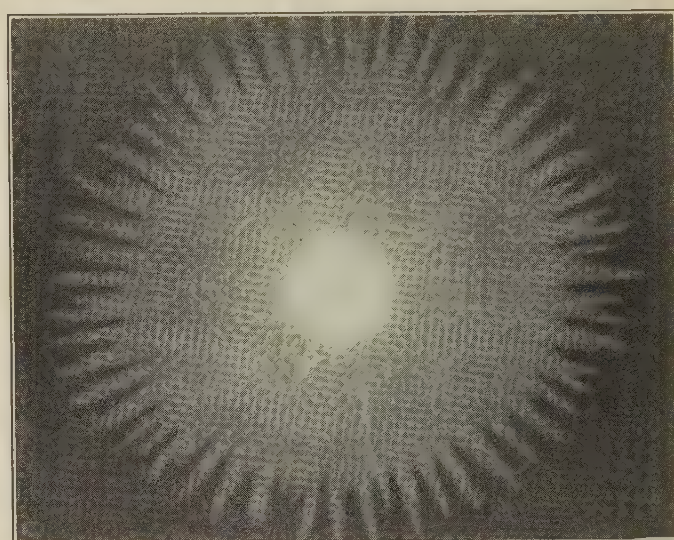

Fig. 18—Positive Figure. Pressure 6 cm.

control plate showing that the light effect was confined to the figure itself and did not to any appreciable extent fog the plate. For control an unexposed plate from the same box of plates was kept in the developer and fixing bath along with, and for the same length of time as, the exposed plate. Visual examination of both the positive and negative figures by means of a compound microscope is more satisfactory than to study the micro-photographs as for the higher magnification the thickness of the emulsion film is greater than can be observed without change of focus. The dark specks are distributed through the emulsion film and not merely in a surface layer.

Changes in Air Pressure. The preceding discussion relates to Lichtenberg figures taken in air under normal atmospheric pressure. Figures taken in a partial vacuum differ radically in appearance and size from those obtained at normal pressures. The size of the

figure increases with reduction in pressure. The quantitative relation between size of figure and pressure of gas is being investigated, but no equation has been

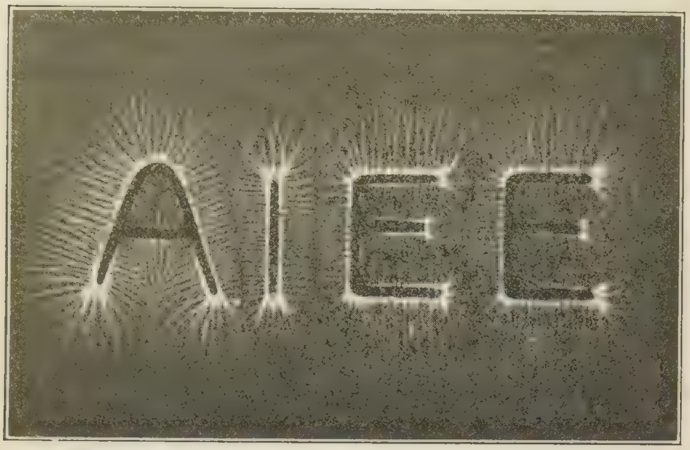

Fig. 19

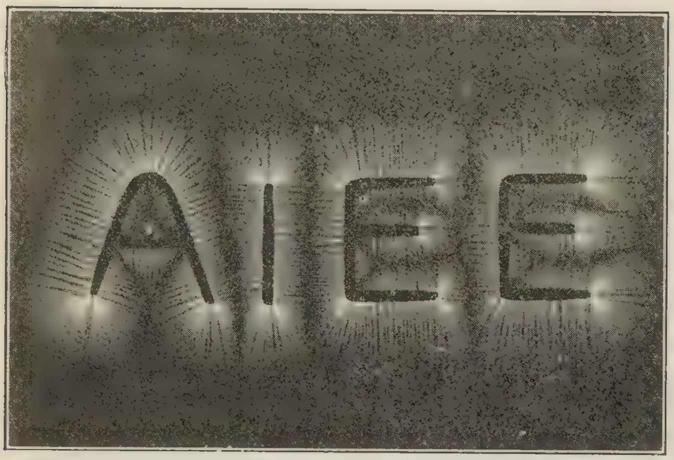

Fig. 20

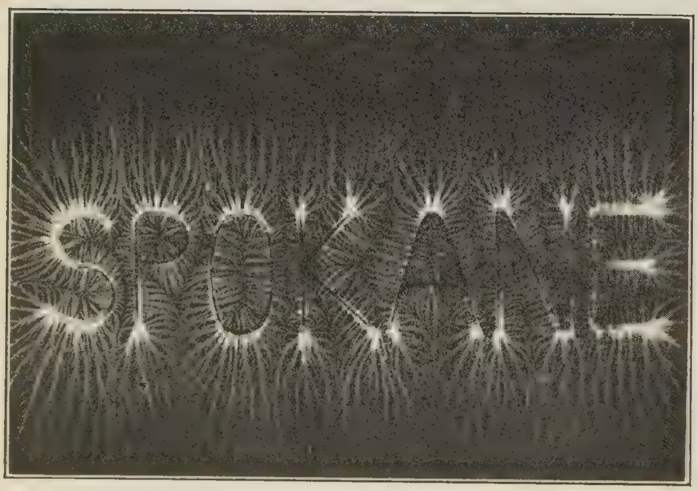

Fig. 21

definitely derived. The appearance of the positive figures varies greatly with the reduction of the air pressure. In Figs. 17 and 18 are shown positive figures for impulses of the same magnitude and wave form at 76-cm. and 6-cm. pressure, (atmospheric) respectively. For the negative figures, the chief differences seem to be increase in size as the pressure is reduced. Experiments on the effect of changes in air pressure are in

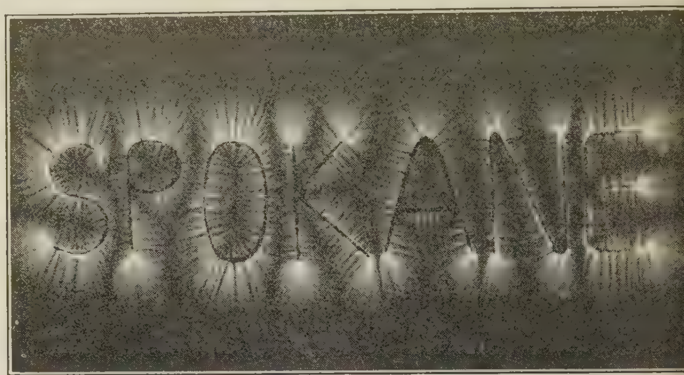

Fig. 22

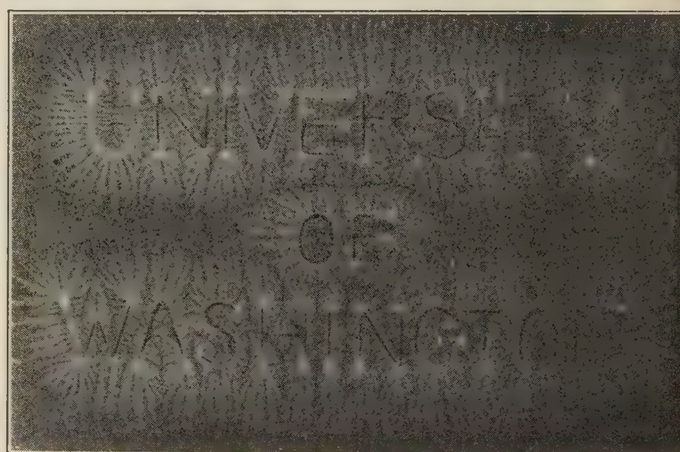

Fig. 23

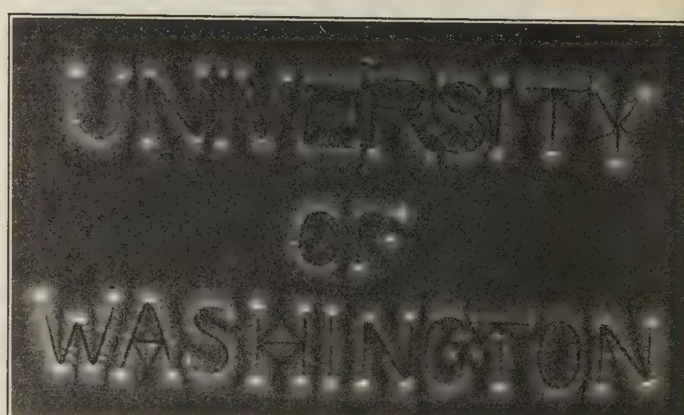

Fig. 24

progress and the results will be published when the investigation is completed. (A series of slides showing positive figures for various air pressures were shown.)

Letter Electrodes. If the electrode in contact with the photographic plate is shaped into the form of

letters, the resulting Lichtenberg figures produce interesting and pleasing effects.

Thus, in Figs. 19 and 20 are shown the positive and negative figures for "A. I. E. E." and in Figs. 21 and 22 corresponding figures for "SPOKANE." In Figs. 23 and 24, having "UNIVERSITY OF WASHINGTON" on the electrode, the exposure was made under reduced air pressure. The change in form is especially apparent in Fig. 23. (A number of slides with electrodes in the form of letters or words.)

SUMMARY

a. The first part of the paper gives a statement of Lichtenberg's discovery and a brief outline of the work that has been done in this field. The second part of the paper deals with work completed or in progress at the University of Washington.

b. Description of the belt generator as a source of steep wave-front impulses suitable for the production of Lichtenberg figures.

c. A comparative study of available types of photographic plates revealed that the Lumière Sigma plate gave best results.

d. Experimental evidence supporting the proposition that for the negative figure electrons are projected over the surface of the plates in a radial direction outwards from the negative electrode.

e. Likewise for the positive figure, the direction of motion of the electrons is towards the positive electrode although the steep-voltage gradient wave, itself, moves radially outwards from the electrode.

f. Experiments are described which prove that light is formed when the electric impulse travels over the plate surface and that light action is the immediate cause for the formation of the photographic record. The sharpness of the figure outlines indicate that the light is produced at the surface boundary of the air with the photographic plate.

g. Experiments are in progress to determine the effects on Lichtenberg figures for changes in air pressure. The size of the figure increases with reduction in pressure and the general structure, of especially the positive figure, changes greatly from the form produced by the given impulse in air at atmospheric pressure.

h. If the shape of the electrode is in the form of letters, sketches, drawings, or other forms, interesting effects may be produced, as is evidenced by Figs. 19 to 24 inclusive.

Although accidents last year showed an increase, the 1927 toll of approximately 95,500 deaths being about 4 per cent higher than in 1926, members of the National Safety Council are reducing the number of industrial fatalities in shops and factories, as is shown in the annual statistical compilation which just has been made public, comprising a pamphlet covering the safety experiences of some 2089 establishments in varied lines.

HAZARD OF TRAILING CABLES ON ELECTRICAL MINING MACHINES

The earlier approvals on electrically-operated mining machines issued by the United States Bureau of Mines from 1914 to 1922 gave but scant consideration to the trailing cables on these machines. As the problem of safeguarding these machines became better understood, the condition of the trailing cable was recognized to be a matter worthy of careful consideration. Consequently, in January, 1922, a conference of machine manufacturers, cable manufacturers, and operators was called by the Bureau of Mines. This conference resulted in quite general adoption of rubber-sheathed cable for this service, which change undoubtedly decidedly improved the service.

As the Bureau accumulated further evidence as to the experience with trailing cables, it became evident that cable splices as usually made were causing many cable failures and bringing about an especially dangerous situation. Hence, in the Bureau's recent approvals, the splicing of trailing cables is forbidden unless such splices are vulcanized.

The liability of two-conductor concentric type cables to short-circuit has been called to the Bureau's attention by one operator. A test in which a 10-lb. weight is dropped a distance of 6 feet on the conductor has been tentatively standardized. The conductor is placed lengthwise on a steel mine rail. The tests are repeated until the conductor is short-circuited either by forcing the conductors together or by the metallic weight itself.

During the past few months, the Bureau has made a number of tests on concentric and other types of cable and the results point to the necessity of radical changes in the construction of concentric cables if such cables are to be admitted as a part of permissible equipment.

TESTING OF PERMISSIBLE BLASTING DEVICES

At its Pittsburgh Experiment Station the United States Bureau of Mines is prepared to conduct tests of blasting devices for the purpose of determining the permissibility of such devices, and approving them as permissible for use in coal mines.

A permissible blasting device for breaking down coal is a device similar in all respects to the sample passed by tests prescribed by the Bureau of Mines to determine its safety for use in coal mines. A permissible blasting device is permissible only when it is used in accordance with the conditions prescribed by the Bureau of Mines.

Schedule 20, "Permissible Blasting Devices; Procedure in Testing, Fees, and Requirements for approval," recently issued by the Bureau of Mines, contains information in regard to the conditions under which blasting devices will be tested. Copies of this schedule may be obtained by addressing the United States Bureau of Mines, Department of Commerce, Washington, D. C.

INSTITUTE AND RELATED ACTIVITIES

New York Section to Hear Lecture on Waves and Crystals

On the evening of Tuesday, November 13th, the New York Section of the Institute will hold its first meeting of the administrative year 1928-29. Dr. Karl K. Darrow, of the Bell Telephone Laboratories, will give a lecture on "Crystals and Waves." This address of a semi-popular character, will be an account of the interactions of crystals with X-rays and electrons, showing that crystals are periodic arrangements of atoms and that electrons and X-rays are periodic similar waves. The talk will be illustrated with lantern slides.

The Executive Committee wishes to express its regret over the cancellation of the October 26 meeting. It will be held, however, at a later date.

The December meeting will be held on the 14th of the month at the Edison Lighting Institute, Harrison, N. J.

Future Section Meetings

Cleveland

Making Sound Visible and Light Audible, by John B. Taylor, Consulting Engineer, General Electric Co. Electrical League rooms, Hotel Statler. November 15.

Joint meeting with Cleveland Chapter, Illuminating Engineering Society. December 13.

Pittsburgh

Transient Phenomena, by K. B. McEachron, Lightning Arrester Engg. Dept., General Electric Co. November 13.

Facsimile Picture Transmission, by Dr. Dayton Ulrey and Dr. V. Zworykin, Research Dept., Westinghouse Electric & Mfg. Co. December 11.

Vancouver

Visit to new technical school. November 6.

Aeroplane Design, by Professor Vernon, University of British Columbia. December 4.

Conference on Impregnated Paper Insulation

Research in the field of impregnated paper insulation is being actively prosecuted in a number of university and industrial laboratories. The Committee on Electrical Insulation, N. R. C., is in touch with much of this work, and it can render a service by bringing together for mutual discussion as many as possible of those who are interested in this field. Therefore, for the purpose of reviewing, discussing, and further coordinating the work which is now under way, it is arranging a conference at the School of Engineering, The Johns Hopkins University, Baltimore, November 16 and 17, 1928. Among those who have accepted invitations to take part in the conference and to report on the progress of the work now under way in their respective laboratories are:

Doctor V. Bush, Massachusetts Institute of Technology; Professor A. H. Compton, University of Chicago; Mr. W. F. Davidson, Brooklyn Edison Company; Professor C. L. Dawes, Harvard University; Mr. C. F. Hirshfeld, Detroit Edison Company; Professor V. Karapetoff, Cornell University; Professor E. B. Paine, University of Illinois; Mr. D. W. Roper, Commonwealth Edison Company; Doctor J. B. Whitehead, Johns Hopkins University; Mr. G. B. Shanklin, General Electric Company; Doctor G. M. J. Mackay, General Electric Company.

Friday, November 16, will be devoted to the reports indicated above, and technical discussion thereon. A meeting of the Committee on Electrical Insulation, N. R. C., will be held on Saturday, November 17, at 9:30 a. m. Upon request, provision will also be made for meetings of any other committees which may be desired. The remainder of Saturday morning will be available for a continuation of the discussion of the research reports. Those who expect to attend are requested to notify Doctor John B. Whitehead at Johns Hopkins University.

Annual Meeting of The A. S. M. E.

The Annual Meeting of The American Society of Mechanical Engineers program covers a wide field of activities. It will open on Monday, December 3, and following preliminary business meetings held during the morning, papers on machine shop practise, hydraulics and applied mechanics will be presented and discussed during the afternoon. Tuesday's sessions will include Machine Shop Practise (II), Industrial Power, Hydraulics (II), Applied Mechanics (II) in the morning; in the afternoon, Machine Shop Practise (III), Education and Training for the Industries of Non-College Types, Material Handling (I) and a public hearing of the Power Test Code. Tuesday evening, the presidential reception and dance will be held. Wednesday morning, Fuels, Management (jointly with A. M. A.), Oil and Gas Power and Railroading will occupy the program. Wednesday afternoon, there will be an illumination session held jointly with the Illuminating Engineering Society, a second Railroad session and the reports of the steam table research. Wednesday evening there will be the Annual Dinner at the Hotel Astor, and Thursday morning's program will include the subject of Central Station Power, a third session on management, a session on aeronautics, and one on lubrication. Thursday afternoon, boiler feed water studies will be presented, followed by a session on fluid meters, a second session on the handling of materials, and a symposium on mechanical springs. Thursday evening the college reunions will be held. Friday morning's sessions will apply to the iron and steel industry, the printing industry, the wood industries with a joint session with A. S. R. E.

Seventh National Exposition of Power and Mechanical Engineering

A feature of the Seventh National Exposition of Power and Mechanical Engineering this year will be a motion picture program running through the entire week of the Show from December 3 to 8 inclusive.

The films will cover a wide field of service, and some of them are being shown for the first time; date and time to be announced later. At present the program includes the following:

"The Age of Speed"; "The Handling of Heat," showing use of Norton refractories in industry; "The Story of Vim Leather," showing production from raw materials to finished products and the various functions and operations through which it passes to actual operation by industry; "The Manufacture of Timkin Steel Roller Bearings," "Freezing Out Fires," demonstrating the effectiveness of carbonic gas as an extinguishing medium as compared with carbon tetrachloride; "Electrical Measuring Instruments," covering the principle and operation, and the voltmeters, ammeters of the permanent magnet, movable coil and movable iron types of instruments, as well as voltmeters, ammeters, watt-meters of the electro-dynomometer type, power factor, frequency meters, synchroscopes and thermo instruments; "Controlling Heat," showing the transmission of energy in the form of heat to work for the comfort of humans; "The Heat Thief," a new film by the Hoffman Specialty Co. "Controlling Fire in the Dip Tank," by Walter Kidde & Co. —"Power," which shows the amazing growth in the use of power since it was first applied industrially about 150 years ago, traces the development of the steam engine from the first crude engines of Newcomen and Watts to those of the present time.

"From Coal to Electricity," discloses the story of the operation of electricity from coal showing the operations and the machines used to do the work.

"Conowingo," which shows the building of one of the important water power projects of the United States. Located on the Susquehanna River in its initial development, it is, second only to the plants at Niagara Falls., Films by Courtesy Stone & Webster Engineering Co.

This program and other features carry a message to the engineering and industrial world and to all who attend the Show.

Among the new equipment this year will be a new line of lighting panels and a new method of interior wiring known as Square Duct, by the Square D Company.

John Fritz Medal to Mr. Hoover

At its regular annual meeting October 19th, the John Fritz Medal Board of Award bestowed its gold medal upon Herbert Clark Hoover. The process of selection for this medal award which occupies an extended period of several years. was made tentatively a year ago by the Board, composed of sixteen recent past-presidents of the four National Societies of Civil, Mining and Metallurgical, Mechanical, and Electrical Engineers, comprising a combined membership of nearly 60,000. The final decision was unanimous.

By this means, the Board sought to express the profession's high appreciation of Mr. Hoover's distinguished attainments as an engineer, particularly in mining operations in this and other countries, and of his great services to his fellowmen. Notable among his engineering achievements is the successful introduction into other countries of improved American mining methods. His scholarly accomplishments too are worthy of mention, especially his translation of the difficult medieval Latin of Agricola's famous book, "De Re Metallica," into readable English. In this enterprise, Mrs. Hoover worked with him.

The citation accompanying the award reads: "To Herbert Hoover, Engineer, Scholar, Organizer of Relief to War-Stricken Peoples, Public Servant." The medal is to be presented to Mr. Hoover at the annual meeting of the American Institute of Mining and Metallurgical Engineers the third week of February 1929 in New York. Within the past few years Mr. Hoover has been made an Honorary Member for Life of the American Society of Civil Engineers, the American Institute of Mining and Metallurgical Engineers, American Society of Mechanical Engineers, by their separate actions.

A. I. E. E. Directors Meeting

The regular meeting of the Board of Directors of the American Institute of Electrical Engineers was held at Institute headquarters, New York, on Thursday, October 18, 1928.

There were present: President R. F. Schuchardt, Chicago; Past President B. Gherardi, New York; Vice-Presidents O. J. Ferguson, Lincoln, Neb., J. L. Beaver, Bethlehem, Pa., E. B. Merriam, Schenectady, N. Y., H. A. Kidder, New York, B. D. Hull, Dallas, Tex.; Directors M. M. Fowler, Chicago, C. E. Stephens, New York, I. E. Moultrop, Boston, H. C. Don Carlos, Toronto, F. C., Hanker, East Pittsburgh, E. B. Meyer, Newark, N. J., J. Allen Johnson, Niagara Falls, N. Y., A. M. MacCutcheon, Cleveland; National Secretary F. L. Hutchinson, New York.

The minutes of the Directors' meeting held August 7, 1928, were approved.

The following minute in memory of Allen M. Schoen, former Vice-President of the Institute, was adopted:

The death on August 15, 1928, of Allen M. Schoen, Chief Engineer of the South-Eastern Underwriters Association and President of the National Fire Protection Association, removed from the profession of electrical engineering one of its most highly esteemed representatives and from the Institute a member who, during much of the time from his admission in 1893, had served with great effectiveness as vice-president, director, committeeman, or Section chairman. From his early years in railway, central station, and manufacturing work through long service with the South-Eastern Underwriters Association and as consulting engineer, his high ability, sound judgment, pleasing personality, and loyal, unselfish devotion to the interests of all concerned won him high respect, and he attained the distinction of being one of the leading fire protection engineers in the country. It is, therefore, with a keen appreciation of the great loss sustained by both the profession and the Institute that the Board of Directors hereby extends to his family and associates its sincere sympathy and orders this minute spread upon its record.

Reports were presented of meetings of the Board of Examiners held September 26 and October 3, 1928, and the actions taken at those meetings were approved. Upon the recommendation of the Board of Examiners, the following actions were taken: 245 Students were enrolled; 126 applicants were elected to the grade of Associate; 26 applicants were elected to the grade of Member; 1 Fellow was reelected; 31 applicants were transferred to the grade of Member; 3 applicants were transferred to the grade of Fellow.

Approval by the Finance Committee, for payment, of monthly bills amounting to $34,084.13, was ratified. The budget for the appropriation year beginning October 1, 1928, was adopted as submitted by the Finance Committee.

The Secretary reported 1162 members (1102 Associates, 57 Members, and 3 Fellows) in arrears for dues for the fiscal year which ended April 30, 1928, and was authorized to remove from the membership list on December 1, 1928, all those whose dues for that year remain unpaid at that time and who have not indicated a desire to continue membership, requesting an extension of time for the payment of the dues.

In accordance with Section 22 of the Constitution, the following "Members for Life" were exempted from future payment of dues: James Burke, Fred B. Corey, M. H. Gerry, Jr., Frederick V. Henshaw, John Mills, Charles Wellman Parks, and Elmer A. Sperry.

Upon the recommendation of the Committee on Student Branches, authorization was given for the organization of a Student Branch of the Institute at Cornell University, Ithaca, N. Y.

In accordance with Section 21 of the By-laws, five members of the Board of Directors were selected to serve on the National Nominating Committee, as follows: Messrs. H. C. Don Carlos, Bancroft Gherardi, H. A. Kidder, A. M. MacCutcheon, and E. B. Meyer.

Mr. G. L. Knight was reappointed a representative of the Institute on the Board of Trustees of the United Engineering Society, for the three-year term beginning in January 1929.

The following representatives of the Institute on the Assembly of American Engineering Council were appointed for the two-year term beginning January 1, 1929: Messrs. H. H. Barnes, Jr., A. W. Berresford, F. L. Hutchinson, Farley Osgood, A. G. Pierce, R. F. Schuchardt, Charles F. Scott, C. E. Skinner, and Calvert Townley.

Specific dates as decided upon by the local committees and officers, were approved for the following Institute meetings, which had been previously authorized: March 20-22, 1929, Cincinnati Regional Meeting; September 3-6, 1929, Pacific Coast Convention; December 2-4, 1929, Chicago Regional Meeting.

Upon the recommendation of the Standards Committee, the following actions were taken: Approved the revision of the definitions section of the A. I. E. E. Wires and Cables Standard No. 30; approved for acceptance as A. I. E. E. Standards, the following standards developed by subcommittees of the Sectional Committee on Scientific and Engineering Abbreviations and Symbols: Standards for Letter Symbols for Electrical Quantities (No. 17g1), Standards for Hydraulic Symbols (No. 17b), and Standards for Aeronautical Symbols (No. 17e).

The design of the reverse of the Lamme Medal was approved as

submitted by the Lamme Medal Committee, the obverse having been approved previously.

Approval was given to the revised Constitution of the American Engineering Standards Committee, which carries with it a change in name to "American Standards Association." Mr. F. D. Newbury was appointed a representative of the Institute on the Standards Council of the American Standards Association (formerly called Main Committee), for the three-year terming beginning January 1, 1929, and Messrs. H. M. Hobart, H. S. Osborne, and L. T. Robinson were reappointed as alternates for the year 1929.

Progress Report No. 6 of the Joint Committee on Welded Rail Joints was received from Professor D. D. Ewing, a representative of the Institute on the Committee.

Invitations were accepted to send representatives to the Second International Conference on Bituminous Coal, at the Carnegie Institute of Technology, Pittsburgh, November 19-24, 1928; to the 100th Anniversary of the Central School of Arts and Manufacturers, Paris, France, May 26-28, 1929; and to the inauguration of President Harvey N. Davis of Stevens Institute of Technology, November 23, 1928. The appointment of the representatives was referred to the President and the Secretary with power.

Other matters were discussed, reference to which may be found in this and future issues of the JOURNAL.

Doctor Acheson Creates New Fund

It was announced at Columbia University by Prof. Colin G. Fink, secretary of the American Electrochemical Society that a prize fund of $25,000 has been presented to it by Dr. Edward Goodrich Acheson, New York inventor, and a member of the Institute since 1888. The fund is to form the basis of an award every second year of a gold medal, and a prize of $1000 to any man who has made a distinguished contribution to any of the branches fostered by the society. Dr. Acheson invented the Acheson graphite, and the tungsten wire of the incandescent lamp owes its existence to "aquadag," an aqueous lubricant of "deflocculated Acheson graphite." In July, 1881 Dr. Acheson was sent as first assistant engineer of the Edison interests to the Electrical Exposition in Paris. He returned to the United States in 1884, and for a time was connected with the Consolidated Lamp Company of Brooklyn, and the Standard Underground Cable Company of Pittsburgh.

Appreciation of Louvain Memorial

The following is the text of a letter recently received from P. Ladeuze, Rector of Louvain University, to Mr. Edward D. Adams and the delegates of the National Societies of Civil, Mining, Mechanical and Electrical Engineers:

It is my duty, in the name of the University of Louvain and in my own personal name, to thank you and the representatives of the Founder Societies of the 'United Engineering Society' for the very kind letter of congratulations which you sent to me from Brussels on the 5th of July.

The words you addressed to me, still full of the immediate impression of our happy and cordial meeting, proved to us all that in your person and in the persons of the delegates, the University of Louvain had found the most sincere and also the most sympathetic friends she could ever find.

I, myself, and all the members of our faculty, will keep forever in our memory the deep emotions of that 4th of July, when it was given to us to come and to remain in close contact with men who are the best representatives of American idealism and of the friendliest cooperators in our work of reconstruction after the war.

The splendid memorial to the American engineers who fell in the war was, without doubt, a very noble conception, a ndone which was most agreeable to us all. It represents so fully the sentiments of the donors and it expresses so adequately the ties of everlasting friendship which exist between your societies and the University of Louvain, that no one could have imagined a better memorial than this great one.

In the spire of the Library tower, the Liberty Bell and the carillon will remain for generations to come—the magnificent proof of your generous help, of your lofty ideals of science and humanity, and of your noble conception of international solidarity. The University of Louvain owes to you all a debt of gratitude which cannot be repaid.

I am happy to thank you also for your presence and the presence of the delegates of the Founder Societies at the celebrations of the 4th of July; presence which was most precious to us, because it allowed us to exchange with you sentiments and words which were to bring us together in an atmosphere of warm and cordial friendship.

The University of Louvain would be much obliged to you if you would communicate the contents of this letter to the members of all the Engineering Societies who helped to build up the splendid memorial.

UNITED ENGINEERING SOCIETY

LIBRARY ENDOWMENT FUND

The Engineering Societies Library is suffering under the same strain to balance service and income as every college and university. In ten years the number of users has more than doubled and the total expense has risen accordingly.

Users expect more and more that the librarian will act as an expert consultant in problems that books can answer. Now, instead of a book, the library assistant is asked to produce a definite answer to a specific question. And to do this, a much higher grade of worker is necessary.

One of the most obvious opportunities for economy is offered in systematic indexing. A great amount of money is spent each year in indexing engineering literature, yet there is no place in America where a man can consult a complete index. As matters are, an inquirer is given three or four hundred volumes of indexes, and told that by looking through all of them, he probably will find everything of real importance on his subject.

Combining these indexes into a single file would make the matter much simpler. It would cost but a fraction of the amount now spent and besides speeding up the rate of answer. Everyone realizes this, but no library has been able to finance it, and the undertaking lags for lack of a benefactor sufficiently far-sighted to realize the permanent help he can give the engineering profession in this way.

Germany has seen it and has compiled an index in connection with its national research department. The Science Museum Library in England is engaged on one now. America has done nothing.

The Engineering Societies Library is the logical place to do the work in this country; but $5000 a year would be a minimum amount required; and $10,000 could be well spent on accumulated material. The task could be done in parts should funds for the whole not become available at once.

PERSONAL MENTION

CARL C. NELSON has resigned from the Westinghouse Electric & Mfg. Co. at East Pittsburgh, Pa. to identify himself with the Electric Machinery Company, Minneapolis, Minn.

THOMAS F. HERRING has resigned from the Bristol Company of Waterbury, Conn., and has accepted a position as general sales manager of the Signal Engineering & Mfg. Company, New York City.

H. D. PANTON, who has been with Francis R. Weller, Consulting Engineer, Washington, D. C., has joined the general engineering staff of the Electric Bond & Share Company and will go as its general engineer to Barranquilla, Columbia.

ROLAND A. PACKARD, who, for the past eight years, has been mechanical engineer for the Ludlow Manufacturing Associates, two years of which were spent in a large plant just south of Calcutta, ironing out construction difficulties, has now returned to the United States as plant engineer of the Smith Paper Company, Lee, Massachusetts.

CHARLES R. HIGSON, who was chief engineer of the Utah Power & Light Company, Salt Lake City, is now superintendent of distribution with responsible charge of the company's entire

system of distribution. In 1926 Mr. Higson acted as chairman of the Local Convention Committee for the Institute's Pacific Coast Convention at Salt Lake City and he also for many years served as secretary and chairman of the Institute's Utah Section.

N. L. Mortensen, Fellow of the Institute, was appointed chief engineer of the Cutler-Hammer Company, Milwaukee, effective September 1. Mr. Mortensen has been associated with the Cutler-Hammer Company for the past 21 years and for the last five years has been assistant to its chief engineer, Mr. T. E. Barnum also a Fellow of the Institute. Mr. Barnum has just been made consulting engineer for the company, and will now be afforded an uninterrupted opportunity to give his attention to special engineering problems and outside engineering relations.

J. W. Young, formerly in the Power and Central Station Design Department of the General Electric Company at Schenectady, but more recently station design engineer for the Duquesne Light Company, Pittsburgh, Chicago, and the Byllesby Engineering & Management Corp. He is now affiliated with the New England Power Association, Boston, Mass. stationed with the Narragansett Electric Company, a subsidiary of the New England Power Association, at Providence, R. I., as Electrical engineer in charge of a newly formed engineering department.

Mr. Edgar H. Felix, technical writer (author of "Using Radio in Sales Promotion"), and broadcasting and merchandising consultant, has joined the staff of the National Electrical Manufacturing Association, to specialize in radio problems. For several years, he was in charge of public relations of station WEAF while it was owned and operated by the American Telephone and Telegraph Company; subsequently he was associated with N. W. Ayer & Son, advertising agents. During the past few years, he has maintained an independent consulting business in connection with commercial broadcasting and broadcast allocation. Mr. Felix joined the Institute in 1919.

Obituary

Robert Clay Jones, who has been a member of the Institute since 1902 and, for many years, was identified with engineering interests in New Zealand, died at Dunedin, New Zealand, August 1928. Mr. Jones was born in Liverpool, 1852, and after completion of his public school education, took a year in chemistry. He almost immediately became interested in electrical operations and began experimenting on electrical subjects; in fact it was he who first demonstrated electric transmission of power in New Zealand, using two series-wound Gramme machines, one as a generator and one as a motor. He also imported the first Swan lamps into New Zealand and exhibited them in operation before the members of the Otago Institute. He superintended the installation of the closed-circuit fire alarm, and was with the shore staff of the Union Steam Shipping Company of New Zealand as chief electrical engineer, making all electric installations on eleven steamers and planning and equipping the company's repair shops, carpenter shops and upholstering department with electric facilities. For the past thirty years he has been identified with Turnbull & Jones, Ltd. and for them, carried out two transmission plans for electric gold dredges to the entire satisfaction of his principals, the Earnsclaugh Gold Dredging Generating, Transmitting and Motor Equipment, the Mataura-Gore transmitting plant and Electrical Pumping interests. He lectured on electricity in many of the principal towns of Otago and was exceedingly active in the promotion of the profession in that section. Mr. Jones has been a member of the British Institution of Electrical Engineers since 1887.

Alexander C. Dogherty, late of the staff of T. Pringle & Son, Ltd., industrial engineers and architects of Montreal, and an Associate of the Institute for the past fifteen years, was drowned in Brome Lake, Quebec, August 10. He was born in Montreal and after graduating from the Victoria Public School, took several technical courses in the Montreal Commercial and Technical High School, with the Council of Arts & Manufacture, the Y. M. C. A., and the International Correspondence School. From 1906 to 1910, his work was in the offices, shops and drafting room of the Northern Electric & Mfg. Co., telephone manufacturers. From 1910-1911, he was power switchboard designer and inspector for Allis-Chalmers-Bullock, and in 1913, he joined his last professional interests, T. Pringle & Son, with whom he served in the varying capacities of draftsman, engineer on power plants, electrical equipment for cotton mills, and pulp mills, and eventually as chief draftsman of their electrical and mechanical division. To quote "he will be greatly missed by his business associates and friends both on account of his professional and business attainments and his genial personality."

F. S. Blackall, vice-president and general manager of the Taft-Pierce Manufacturing Company of Woonsocket, R. I. and a member of the Institute since 1897, died at his summer home at Woodmont, Conn. October 6. Mr. Blackall was of old American stock, born in Brooklyn, New York, 1865. He received his education in the New York Public Schools and Berlin (Germany) Gymnasium. From 1885 to 1905 he was construction engineer and contractor handling sales and supervising installation of electric power transmission machinery, as president of Blackall & Baldwin Co. In 1903 he identified himself with the Taft-Pierce Manufacturing Company of Woonsocket as its engineer, vice-president and general manager of precisions machinery. He was also president of R. Hoe & Company, of New York and chairman of R. Hoe & Co., Ltd., London, of printing presses. His last work was the general supervision of all operations for his company. The companies with which he was associated at the time of his death were many and varied. He was president of the Interchangeable Parts Company, vice-president and general manager of the Mott Haven Company and director of Parks & Parks, Inc. Formerly he was vice-president and managing director of the Ottoman-American Company which held title to the Chester concessions, taking them over from Rear Admiral Colby M. Chester, who obtained them from the Turkish Government. Mr. Blackall resigned from the Board in 1923. Mr. Blackall served the New York National Guard for seven years as a member of the Seventh Regiment and for three years during the World War he was a special intelligence officer for the British and American governments in Europe. He was a member of the Academy of Arts and Sciences and the Y. M. C. A.; also The American Society of Mechanical Engineers, the American Association for the Advancement of Science, the American Geographical Society, the Engineers Club of New York, the Union League (New York) and the Detroit Athletic Club.

Theodore C. Roberts, consulting engineer, and a member of the Institute since 1916, died suddenly September 28, at his home, 468 Riverside Drive, New York City. Mr. Roberts was a native of New Orleans. After completing his grade school work he entered upon an electrical engineering course at Tulane University, supplementing this later with a further special course in electrical engineering at Colorado College. From 1894 to 1900, he has filled many responsible positions at the Canon City and Florence offices of the Colorado Bell Telephone Company, with the Canon City Light, Heat and Power Company, and the Teluride Power Company, where he worked with Mr. Ralph D. Mershon on high-tension experimental work. His subsequent electrical activities included service as electrical engineer for the United States Reduction and Refining Company in charge of design and construction, chief engineer for the Arkansas Valley Railway Light and Power Company at Pueblo and chief engineer of the United Verde Copper Company, the United Verde & Pacific Railroad, the Verde Tunnel & Smelting Railroad and the Verde Utility & Improvement Company, four years in designing and constructing railroads and equipment aggregating approximately ten million dollars in value. Mr. Roberts was closely associated with the Guggenheim interests in Colorado and was also chief engineer for the H. M. Byllesby Company. While in

Arizona, he was identified with the interests of the late Senator W. A. Clark. During the world war, he was engaged in the manufacture of chemicals and dyes, and subsequent to that seavice, he was chosen assistant to the president of the Columbia Graphophone Company. Since 1923, Mr. Roberts has devoted most of his time to consulting engineering and the writing of scientific articles. He joined the Institute in 1916 as an Associate, but advanced the next year to the grade of Member. He was a member of the four national engineering bodies, Civil, Mechanical, Mining, and Electrical; of the Engineers Club; was a thirty-second degree Mason; belonged to the Columbia Yacht Club, and the Country Clubs of Norwalk, Connecticut, and Prescott, Arizona.

Addresses Wanted

A list of members whose mail has been returned by the postal authorities is given below, together with the addresses as they now appear on the Institute records. Any member knowing the present address of any of these members is requested to communicate with the Secretary, at 33 West 39th St., New York.

All members are urged to notify Institute headquarters promptly of any changes in mailing or business address, thus relieving the member of needless annoyance and assuring prompt delivery of Institute mail through the accuracy of our mailing records, and the elimination of unnecessary expense for postage and clerical work.

Theodorus De Langen, 1310 W. Michigan Ave., Jackson, Mich.
R. A. Drake, 2905 La Salle St., Los Angeles, Calif.
R. P. Dunmire, 7014 Wayne Ave., Bywood, Upper Darby, Pa.
A. Hirth, 1477 W. 9th St., Brooklyn, N. Y.
David Humphreys, Deer Lake, Newfoundland.
Edward H. Hutmire, Box No. 3, Angola, Ind.
A. C. Jefferis, Newcastle, Wyo.
Francis E. Kelley, 53 Gorham Ave., New Haven, Conn.
J. Losinsky, c/o Dr. Minkin, 1291 Grant Ave., New York, N. Y.
H. Perlesz, P. O. Box 783, Milwaukee, Wis.
H. Reydon, 141 W. 69th St., New York, N. Y.
Harry A. Wintermute, Apt. 12, 730 Park Ave., Plainfield, N. J.

A. I. E. E. Section Activities

PAST SECTION MEETINGS

Atlanta

Annual Meeting. Report of D. H. Woodward, Secretary-treasurer. The following officers were elected: Chairman, H. L. Wills; Vice-chairman, W. F. Oliver; Secretary-treasurer, W. F. Bellinger. A dinner preceded the meeting. October 4. Attendance 20.

Chicago

Engineering Problems of the Utilities of Metropolitan Chicago, by Loran D. Gayton, City Engr.; E. J. Kelly, chief engr., Sanitary District; Patrick J. Lucey, former Member Illinois Commerce Commission; J. F. Gilchrist, Vice-president, Commonwealth Edison Company; W. O. Kurtz, General manager, State Area, Illinois Bell Telephone Company; Theo. V. Purcell, Vice-president, Peoples Gas, Light & Coke Company. A dinner preceded the meeting. September 24. Attendance 625.

Cincinnati

Electrical Distribution, by D. K. Blake, General Electric Company. Illustrated with slides. September 13. Attendance 55.

Dallas

Recent Developments in Transmission and Reproduction of Sound, by J. T. Devine, District Manager, Electrical Research Products Company. September 17. Attendance 101.

Detroit-Ann Arbor

A Trip Through Africa, by H. H. Emmons, Attorney. Illustrated. A dinner preceded the meeting. September 25. Attendance 88.

Erie

Measuring Electrical Energy for Public Use, by H. P. Sparkes, Special Engineer, Westinghouse Electric & Mfg. Company. September 18. Attendance 90.

Fort Wayne

Social Meeting. September 27. Attendance 40.

Indianapolis-Lafayette

1928 Developments in Radio Receiving Sets, by R. J. Kryter, Presto-Lite Battery Corp. Meeting followed by a smoker. October 5. Attendance 50.

Minnesota

Recent Developments in Outdoor Lighting, by P. B. Reed, General Electric Company. Illustrated with slides. September 24. Attendance 20.

Pittsburgh

The New Isolated-Phase Switch House of the Duquesne Light Company on Brunot's Island, by E. C. Stone, System Development Manager, Duquesne Light Co. The boat *Manitou* was used to transport the membership from Pittsburgh to Brunot Island. The meeting was held on the boat and was followed by an inspection trip through the power plant and switch house. September 18. Attendance 367.

St. Louis

Does the Institute Accomplish Its Object, by C. P. Potter, Chairman.

Talk by R. F. Schuchardt, National President, A. I. E. E., who gave a number of helpful suggestions for carrying on the engineering work and programs of the Section. September 19. Attendance 75.

Seattle

History and Purposes of the A. I. E. E., by G. E. Quinan, Vice-President, District No. 9, A. I. E. E. The Annual Dinner preceded the meeting. September 18. Attendance 116.

Sharon

A Survey of Present-Day Research and Science, by A. M. Dudley Westinghouse Electric & Mfg. Co. Motion picture, entitled "The Story of Explosives," was shown. October 2. Attendance 150.

Toledo

Steam Production, by E. L. McBee, Asst. Supt., Steam Production of the Toledo Edison Company. September 21. Attendance 38.

Toronto

Social Meeting. September 28. Attendance 103.

Some Aspects of Mathematics in Engineering, by R. E. Doherty, General Electric Co. October 12. Attendance 57.

Urbana

Recent Research in Electrical Engineering, by Prof. E. B. Paine, University of Illinois. May 3. Attendance 93.

Annual Business Meeting. The following officers were elected: Chairman, J. K. Tuthill; Secretary, M. A. Faucett. May 21. Attendance 15.

Vancouver

Inspection Trip to Allouette Power House, B. C. E. R. September 8. Attendance 29.

The Modern Page Printing Telegraph Set, by C. B. Diplock, Supt. of Maintenance, B. C. Telephone Company. October 3. Attendance 58.

A. I. E. E. Student Activities

STUDENT BRANCH ORGANIZED AT UNIVERSITY OF SOUTH CAROLINA

The formation of a Student Branch of the Institute at the University of South Carolina was authorized by the Board of Directors on June 27, 1928, and the Branch was organized on September 24th, when the following officers were elected:

W. Edwin Eargle, Chairman; George P. Watson, Vice-Chairman; Leroy A. Griffith, Secretary-Treasurer. Additional members of the Executive Committee are Frank H. Lucas, Charles H. Frick, and Charles A. Riley. At a meeting held on October 9th, committees were appointed. Professor Thomas F. Ball has been appointed Counselor of the Branch.

BRANCH MEETINGS

Alabama Polytechnic Institute

Talk by Chairman W. P. Smith on the purposes and activities of the Branch. Discussion of plans for the year. J. B. Paisley elected Vice-chairman. September 20. Attendance 57.

Radium and My Experiences with It, by Prof. A. J. Dunstan, Electrical Engineering Dept. September 27. Attendance 56.

Operation of the Electric Ice Plant in Bay Minette, Ala., by P. V. Pardon, student, and

History of the Electrical Laboratory at the Institute and Improvements That Are To Be Made, by T. C. Ingersoll, student. October 4. Attendance 49.

University of Arkansas

Business Meeting. B. H. Dorman was elected Secretary-Treasurer. September 26.

University of California

Chairman Hyde and Prof. T. C. McFarland, Counselor, reported upon the Pacific Coast Convention at Spokane. Chairman Hyde outlined plans for the semester and appointed committees. Refreshments were served after the meeting. September 13. Attendance 25.

Banquet. Prof. H. B. Langille was toastmaster. Prof. T. C. McFarland, Counselor, welcomed 40 new members. B. D. Dexter, Chairman, San Francisco Section, gave a talk on the aims and ideals for the A. I. E. E. Prof. Joel Hildebrand, Chemistry Dept., was the principal speaker and delivered a paper on the scientific advances of the present day. Entertainment followed the talks. October 4. Attendance 81.

Clarkson College of Technology

Testing of Big Guns, by Dr. Joseph E. Rowe, formerly Chief Ballistician at the Aberdeen Proving Ground, now President of Clarkson Memorial College. Prof. A. R. Powers, Counselor, gave a brief history of the A. I. E. E. Student activities. October 9. Attendance 51.

Clemson Agricultural College

After a brief business session the following talks were given:

Civilization and the Engineer, by L. F. Sander;

Power Supply for Railway Signals, by C. R. Martin;

New Theories of Electrons, by R. L. Sweeny, and

Current Events, by W. G. Parrott. October 11. Attendance 18.

University of Colorado

The Value of the A. I. E. E. to the Engineering Student, by Dean H. S. Evans of the College of Engineering. Herbert S. Sands, Consulting Engineer, Denver, gave a report on the Summer Convention of the A. I. E. E. held in Denver in June. October 3. Attendance 45.

Colorado Agricultural College

The Aims and Purposes of the A. I. E. E., by Prof. H. G. Jordan, Counselor. September 14. Attendance 20.

University of Denver

What Happens When a Graduate Starts to Work for the General Electric Company, by E. E. Weyerts, alumnus, General Electric Co. October 5. Attendance 13.

University of Detroit

The Uses and Construction of the Lead-Acid Type of Storage Batteries, by W. C. Leingang, Service Engr., Detroit Branch, Electric Storage Battery Co. Illustrated with three reels on the construction of different types of storage batteries. September 27. Attendance 25.

Drexel Institute

Talk by Dean R. C. Disque of Drexel Institute on the advantages of the five-year course offered at the Institute and the great importance of studying the lives of famous men in the electrical profession. Prof. E. O. Lange, Counselor, emphasized the advantages of having the students prepare and deliver the programs and the necessity of preparing seminar papers for prize competition. Program and By-Laws Committees were appointed by Chairman Way. October 5. Attendance 14.

Georgia School of Technology

Prof. E. S. Hannaford, Counselor, gave a talk on the aims and ideals of the Branch and the A. I. E. E. in general, and a general outline of the plans of the Branch for the year. He also made announcements regarding the Regional Meeting to be held in Atlanta. October 5. Attendance 54.

University of Idaho

Electrical Installation in the Lewiston Lumber Mill, by S. W. Blore, student. The meeting was preceded by the biennial Engineers' Day banquet. May 4. Attendance 34.

Business Meeting. May 18. Attendance 19.

Lafayette College

Business Meeting. A committee was appointed to draw up By-laws for the Branch. September 22. Attendance 24.

Business Meeting. Voted to adopt the Branch By-laws drawn up by the Committee on By-laws. The following officers were elected: Chairman, H. W. Lovett; Vice-Chairman, C. A. Corson. October 6. Attendance 21.

University of Maine

Importance of Merchandising in Light and Power Companies, by R. N. Haskell, Vice-President, Bangor Hydro-Electric Co.

60,000-Kw. Steam-Turbine Generator Set, by K. W. Downing, student. Prof. W. E. Barrows, Jr., Counselor, spoke on the aims of the Student Branch. Refreshments. October 10. Attendance 40.

Marquette University

Personality as an Asset in Business, by I. H. Offner, Northwestern Mutual Life Insurance Co. A short talk on membership was given by Mr. Windegatz. Lunch was served after the meeting. October 4. Attendance 34.

Mississippi A. & M. College

Prof. L. L. Patterson, Counselor, gave a short address on the organization and scope of A. I. E. E. and its benefits to the electrical engineer. Election of officers. September 20. Attendance 30.

Newark College of Engineering

Bakelite, by E. T. Toth, Bakelite Company of America. Magazine and Program Committees appointed. October 8. Attendance 38.

University of New Hampshire

Talks on summer work by E. B. Moore, T. Elliott, Bryce Attwood, A. R. Neal, M. W. Cummings, T. W. Colby and N. R. Pierce, seniors. Prof. L. W. Hitchcock, Counselor, made a few comments on several of the talks. September 22. Attendance 33.

Color for Amateur Movies, by A. R. Neal, senior, and

Opportunities with the Westinghouse Electric & Mfg. Company, by M. W. Cummings, senior. Prof. F. D. Jackson compared the General Electric Co. and the Westinghouse Electric & Mfg. Co. courses. September 29. Attendance 34.

College of the City of New York

Inspection trip to Schenectady Works, General Electric Co. September 16, 17, and 18. Attendance 12.

Business Meeting. Discussion of programs for this term. Discussion of preparation of papers, one of which will be presented at the 1929 New York Section Student Branch Convention. October 4. Attendance 23.

University of North Carolina

Prof. P. H. Daggett, Prof. J. E. Lear and Mr. T. B. Smiley of the faculty gave talks for the benefit of new members of the Branch. A tour of inspection was made to the various laboratories, and refreshments were served. Committee appointed to consider proposed by-laws. September 28. Attendance 31.

University of North Dakota

Still film shown and description given by Arnold Niehus. Discussion of plans for the year. Appointment of committees. October 4. Attendance 16.

Ohio Northern University

Smoker. Talks by Prof. I. S. Campbell, Counselor, and Professors Webb, Elbin, Alcroft, Whitted and Fairchild, Dr. Smull and Dean Needy. Refreshments served. September 27. Attendance 45.

University of Oklahoma

Business Meeting. The following officers were elected: Chairman, Charles Ittner; Secretary, LeRoy Moffett, Jr. May 22. Attendance 10.

Summer Experiences Installing PBX Switchboards, by L. R. Moffett, Jr.;

Summer Experiences with the Southwestern Bell Telephone Co., by Wallace Fullerton, and

A Trip Around the World, by Mr. Edwards. Prof. F. G. Tappan, Counselor, gave a talk on the value of the A. I. E. E. to electrical engineering students. Professors Bullen and Almquist gave short talks. Refreshments were served. October 11. Attendance 32.

Pennsylvania State College

Cider-Feed and Smoker. Members of the faculty gave short talks and Chairman Bair extended an invitation to new men to join the Student Branch. October 3. Attendance 167.

University of Pittsburgh

Business Meeting. The following officers were elected: Chairman, J. B. Luck; Vice-Chairman, K. A. Taylor; Secretary-Treasurer, J. G. Hoop. September 28. Attendance 34.

Men in Industry, by E. S. McClelland, Personnel Manager, Westinghouse Electric & Mfg. Co. October 5. Attendance 68.

Rensselaer Polytechnic Institute

The Manufacture of Steel, by G. E. Thackray, C. E., '78 Rensselaer, Consulting Engineer, Bethlehem Steel Co. Joint meeting of local branches of A. S. C. E., A. S. M. E., A. I. Ch. E. and A. I. E. E. October 10. Attendance 300.

Rhode Island State College

Professor Wm. Anderson, Counselor, spoke on the advantages of A. I. E. E. membership. He suggested that a paper be prepared for the Student Convention and that the Branch plan an exhibition or open house for next spring. The following elections took place: President, F. E. Caulfield; Vice-President, T. H. Lloyd; Senior member, Program Committee, R. V. P. Cahill. September 26. Attendance 14.

Professor Wm. Anderson gave a talk on "My Visit to Schenectady," in which he described developments witnessed during five weeks at the General Electric Company's factory. October 3. Attendance 23.

Manufacture of Vacuum Tubes, by Nicholas Abbenante, student;

The Lighthouse Service, by C. F. Easterbrooks, student, and

Marine Radio Traffic, by A. Z. Smith. October 10. Attendance 13.

Rutgers University

Facsimile Photo-Radio Transmission, by Henry Shore, Radio Corporation of America. Prof. Paul S. Creager nominated for Counselor. October 8. Attendance 25.

University of Santa Clara

Business Meeting. Plans for securing speakers and programs for meetings were discussed. The following officers were elected: Chairman, J. L. Quinn; Vice-Chairman, Geo. Gabel; Secretary-Treasurer, T. L. Selna. August 22. Attendance 17.

Doings at the A. I. E. E. Convention held at Spokane, by J. L. Quinn, Chairman, A. I. E. E. Branch. Joint meeting A. I. E. E. Branch and Santa Clara Engineering Society. September 25. Attendance 93.

Business Meeting. Enrolment of new members discussed. Chairman Quinn have additional details of the papers delivered at the Pacific Coast Convention at Spokane. October 3. Attendance 10.

University of South Carolina

Organization Meeting. Meetings and Papers, Publicity and Membership Committees were appointed. Professor T. F. Ball, Counselor, made announcements regarding the Regional Meeting to be held in Atlanta. October 9. Attendance 14.

University of South Dakota

Business Meeting. Decision made that meetings of Branch will be held at 4:30 o'clock on Monday of every second week. Next meeting to consist of the narration of the summer experiences of those present. September 26. Attendance 14.

Talks on summer experiences by several students. Plans for the homecoming "Dakota Day" were discussed. October 8. Attendance 14.

University of Southern California

Business Meeting. The following officers were elected: Chairman, David Stanfield; Vice-Chairman, Lumir Slezak; Secretary, Arthur Cutts; Treasurer, Donald Howard. Robert Goode and Zoeth Cummings elected representatives on the Engineer's Council. May 17.

Advantages and Purposes of the A. I. E. E., by H. L. Caldwell, Bureau of Power and Light of the City of Los Angeles, and Chairman, Los Angeles Section, A. I. E. E. Dean P. S. Biegler, Counselor, spoke briefly of the plans for the new College of Engineering at the University. Membership Committee appointed to attempt to increase the number of enrolled Students in the Branch. Committee appointed to take charge of student papers and research work. Announcements concerning field trips and plans for future meetings. September 27. Attendance 35.

Syracuse University

Business Meeting. Two students selected to give papers at next meeting. Prof. C. W. Henderson, Counselor, gave a talk on the Institute and some of its early activities. Election of officers. October 2. Attendance 20.

Supervisory Control, by Mr. Allen, student, and

Statistical Data of the Power Industry, by Mr. App, student. October 9. Attendance 22.

Texas A. & M. College

Two talks on the aims and purposes of the Student Branches of the A. I. E. E. and plans for the coming year. October 5. Attendance 110.

University of Texas

Prof. J. A. Correll, Counselor, gave a talk on the history and purposes of the A. I. E. E. September 27. Attendance 12.

Virginia Polytechnic Institute

Organization and Functions of the Branch, by Prof. Claudius Lee, Counselor. Election of officers. September 26. Attendance 35.

Washington State College

Talk by Prof. R. D. Sloan, Counselor, on the relation of the Student Branches to the national society. The following officers were elected: President, J. B. Danielson; Secretary, L. H. Wollenberg; Treasurer, Lawrence Koehler. October 3. Attendance 25.

West Virginia University

Business Meeting. Program Committee appointed. The following officers were elected: President, C. C. Coulter; Vice-President, I. F. Vannoy. September 24. Attendance 30.

Creosoted Wood Cable Conduits, by J. K. Gwinn and H. V. DeJounett; *Transformers and Transformer Oils*, by M. C. Clark; *Outside Plant Engineering*, by Ivan Vannoy; *Effects of Corona in Various Gases on Insulation and Losses*, by F. H. Backus; *Electric-Arc Welding*, by W. S. Bosley; *Conowingo Dam Project*, by C. C. Coulter; *Gasoline-Electric Buses*, by G. I. Bumer. Critics were: M. S. Diaz and P. E. Davis. October 1. Attendance 28.

Oil Dehydration, by P. E. Davis; *Rust Prevention in Iron and Steel*, by Earl Milan; *Improvements in the Turbo-Generator*, by R. H. Pell; *Electrical Equipment in the Holland Tunnel*, by T. D. Nixon; *First Aid to the Injured*, by Albert Izzo; *Constant Current Generators*, by W. S. McDaniel; *Viceroy of India*, by R. N. Kirchner; *Electric Recorder*, by S. N. Giddings. October 8. Attendance 30.

University of Wyoming

Different School Organizations and Their Relation in Every Day Life, by Dean Rhoades, Engineering School. Prof. G. H. Sechrist, Counselor, gave a brief talk on the value of being an enrolled Student of the A. I. E. E. and being a member after graduation. October 9. Attendance 15.

Engineering Societies Library

The Library is a cooperative activity of the American Institute of Electrical Engineers, the American Society of Civil Engineers, the American Institute of Mining and Metallurgical Engineers and the American Society of Mechanical Engineers. It is administered for these Founder Societies by the United Engineering Society, as a public reference library of engineering and the allied sciences. It contains 150,000 volumes and pamphlets and receives currently most of the important periodicals in its field. It is housed in the Engineering Societies Building, 29 West Thirty-ninth St., New York.

In order to place the resources of the Library at the disposal of those unable to visit it in person, the Library is prepared to furnish lists of references to engineering subjects, copies or translations of articles, and similar assistance. Charges sufficient to cover the cost of this work are made.

The Library maintains a collection of modern technical books which may be rented by members residing in North America. A rental of five cents a day, plus transportation, is charged.

The Director of the Library will gladly give information concerning charges for the various kinds of service to those interested. In asking for information, letters should be made as definite as possible, so that the investigator may understand clearly what is desired.

The library is open from 9 a. m. to 10 p. m. on all week days except holidays throughout the year except during July and August when the hours are 9 a. m. to 5 p. m.

BOOK NOTICES, Sept., 1-30, 1928

Unless otherwise specified, books in this list have been presented by the publishers. The Society does not assume responsibility for any statement made; these are taken from the preface or the text of the book.

All books listed may be consulted in the Engineering Societies Library.

APPAREILS ET METHODES DE MESURES MECANIQUES.

By Jules Raibaud. Paris, Armand Colin, 1928. 215 pp., 7 x 5 in., paper. 9 fr.

A concise description of the methods and apparatus used for measuring the basic quantities of experimental mechanics—time, speed, acceleration, mass, force, work and pressure. The text is concise and critical. It brings to experimenters in scientific laboratories material that usually must be collected from many different works.

AUFBAU UND ENTWICKLUNGSMOGLICHKEITEN DER EUROPAISCHEN ELEKTRIZITATSWIRTSCHAFT.

By München, R. Oldenbourg, 1928. 511 pp., illus., diagrs., maps, tables, 10 x 7 in., cloth. Price 20 r. m.

A detailed economic study of the development and future possibilities of electric power generation in Europe. The condition of the industry in Germany is covered with great thoroughness and the more important developments in other countries are described. Financial statistics are given for all the important European electrical undertakings. The book will be of great value to those in need of financial and engineering statistics.

COLLOID CHEMISTRY.

By The Svedberg. 2d edition. N. Y., Chemical Catalog Co., 1928. (American Chemical Society. Monograph series). 302 pp., illus., diagrs., tables, 9 x 6 in., cloth. $5.50.

In 1923 Professor Svedberg gave a series of lectures at the University of Wisconsin in which he presented a general survey of colloid chemistry, with special attention to recent developments in technique. These lectures form the basis of this book, which now appears in a revised and enlarged edition.

The new issue includes accounts of recent advances. More space is given to the results of X-ray analysis, to methods of ultramicroscopy and other improvements in technique, particularly those developed by the author and his coworkers.

COLLOID CHEMISTRY OF THE RUBBER INDUSTRY.

By E. A. Hauser. Lond. & N. Y., Oxford University Press, 1928. 55 pp., illus., 10 x 6 in., boards. $1.50. (Gift of Amer. Branch).

Contains the first series of Gow lectures on the colloid chemistry of the rubber industry, delivered at University College, London, in 1927. Dr. Hauser provides a brief survey of the work already done in this field and indicates the directions in which further work is desirable. He explains the methods of investigation which have been used successfully and suggests methods and means of experimentation which may lead to further knowledge.

COURS D' AERONAUTIQUE.

By Emile Leroux. Paris, Ch. Béranger, 1927. 382 pp., diagrs., tables, 10 x 6 in., paper. 56 fr.

Aeronautics is here presented as taught in the School of Applied Marine Engineering in France. The author, an engineer in the aeronautic corps, has combined in one volume the important data upon all branches of the subject and produced a most satisfactory text. The book is intended for engineers already well grounded in general engineering.

DETERMINATION OF MINERALS UNDER THE MICROSCOPE.

By John W. Evans. Lond., Thomas Murby & Co., 1928. 110 pp., illus., diagrs., 8 x 5 in., cloth. 7/6.

The purpose of this book is to assist students to realize the principles on which the optical study of minerals rests without the use of advanced mathematics. It discusses in considerable detail the petrological microscope and its accessories, the methods used in identifying crystals with its aid, and the optical theory involved.

ELECTRIC CIRCUITS, THEORY AND APPLICATIONS, v. 1; Short-Circuit Calculations and Steady-state Theory.

By O. G. C. Dahl. N. Y., McGraw-Hill Book Co., 1928. 390 pp., diagrs., tables, 9 x 6 in., cloth. $5.00.

The purpose of this book is to present the engineering aspects of circuit theory and to provide the methods and tools required for the analysis of modern power-circuit problems. The theory is presented in the language of the engineer and from his point of view. Numerous illustrative examples, based on actual data, are worked out in the text.

ELEMENTS OF ALTERNATING CURRENTS AND ALTERNATING-CURRENT APPARATUS.

By J. L. Beaver. 2d edition. N. Y., Longmans, Green & Co., 1928. 393 pp., illus., diagrs., 10 x 7 in., cloth. $4.00.

A text-book of college grade, intended for beginners in the subject and planned for sixty-hour to ninety-hour courses. The large number of questions and problems is a feature of the work. The new edition has been largely rewritten and various topics have been treated more fully.

ELLIPTISCHE FUNKTIONEN.

By R. König and M. Krafft. Berlin, Walter de Gruyter & Co., 1928. 263 pp., 10 x 7 in., paper. 13.–r. m.

A very satisfactory introduction to elliptical functions. The authors have not attempted a compendious treatment but have produced a text-book which begins with the simplest analytical functions and proceeds, step by step to the most complex. The treatment develops the subject systematically and organically, and the book equips the student for understanding the classic works in this field.

EVOLVENTENVERZAHNUNG.

By Hans Friedrich. Berlin, Julius Springer, 1928. (Theoretische untersuchungen für maschinenbau u. bearbeitung, heft 1). 77 pp., diagrs., tables, 10 x 7 in., paper. 7.–r. m.

A theoretical and practical treatise on involute gears. The aim is to present clearly and simply the basic principles that

underly the development of involute tooth profiles and the best methods of cutting involute gears. Among the subjects discussed are the limiting conditions for tooth surfaces, the laying-out and cutting of gears, spur and bevel gears, and helical gears.

Franzosischer Sprachfuhrer fur den Fernsprechweitverkehr.

By Albert Lang. Berlin, Weidmannsche Buchhandlung, 1928. 120 pp., 9 x 6 in., cloth. 9.–r. m.

With the rapid extension of international telephony, the language difficulty becomes increasingly troublesome. The author of this work endeavors to facilitate telephony between Germany and France by this dictionary of French and German terms.

The first section contains about 550 phrases arranged according to the divisions of telephone service. The second section is a dictionary of French and German technical words, containing all those ordinarily used in telephony.

Die Galvanotechnischen Bader.

By Alfred Wogrinz. Berlin, M. Krayn, 1928. 121 pp., tables, 10 x 7 in., paper. 9.–r. m.

This small book contains selected methods for analyzing and testing the various materials and baths used by electroplaters, together with a collection of physical and chemical data used by them. The work is intended to supplement standard tests on electroplating.

The methods are given in detail and are accompanied by useful comments based on the author's practical experience.

Gasfernversorgung Westsachsens.

By L. Litinsky. Lpz., Kreishauptmannschaft. Leipzig, Landesplanung Westsachen, 1928. 31 pp., maps, 9 x 6 in., paper. 1,50 r. m. (For sale by the Author, Lpz., 027, Thiemstr. 6).

This pamphlet presents a plan for consolidating the gas works of Saxony into a single system which will supply gas to the entire country.

Geschichtliche Einzeldarstellungen aus der Elektrotechnik, vol. 1.

By Elektrotechnischer Verein. Berlin, Julius Springer, 1928. 98 pp., illus., ports., 10 x 6 in., paper. 6.–r. m.

The Electrotechnischer Verein inaugurates with this work a series of publications devoted to the history of electrical engineering. Each publication is to deal with some special topic.

This first number treats of transformers and meters. The first article, by L. Schuler, traces the evolution of the transformer from the work of Faraday and Henry on induction down to the twentieth century. This is followed by the classic papers of Gisbert Kapp and Dolivo-Dobrowolsky on transformer theory. The final article is a history of electricity meters by W. Stumpner.

Handbuch der Landmaschinentechnik, v. 1, pt. 1.

By Georg Kühne. Berlin, Julius Springer, 1928. 132 pp., illus., 11 x 8 in., paper. 18.–r. m.

Previous books on argicultural machinery have been largely descriptive and economic. Much has been written on the machines developed by various manufacturers, and on the value of machinery in farming, but no comprehensive book has appeared in which the design and construction of farm machinery are treated from the point of view of the mechanical engineer.

The present book is the first quarter of a work intended to fill this gap in the literature. It is devoted to machines for working the soil by animal power or by rope-drive. It discusses plows, harrows, cultivators, etc., paying special attention to the structural requirements of the various parts, the most suitable materials, and proper design.

Introduction to Modern Physics.

By F. K. Richtmyer. N. Y., McGraw-Hill Book Co., 1928. 596 pp., ports., tables, 9 x 6 in., cloth. $5.00.

A discussion of the origin, development and present status of some of the more important classical and modern concepts of physics, intended to give a correct perspective of the growth and present trend of the science as a whole. This perspective is necessary, the author feels, as the basis for intensive study of any subdivision of the subject.

The text first gives a historical review of physics up to 1890, which date is taken as the beginning of the modern period. The remainder of the book pays attention particularly to the two great problems of today; the reconciliation of the wave theory of light with the quantum theory, and the structure of matter.

Kraftwerksbauten.

By Siemens-Schuckertwerke. Berlin, V. D. I. Verlag, 1928. 101 pp., illus., 12 x 9 in., bound. 5.–r. m.

A collection of photographs and plans of modern steam-electric and hydroelectric power plants and transformer stations designed by the Siemens-Schuckert firm. Among them are the Fortuna II at Cologne, the Leverkusen, the Unterweser, the Shannon River and the Tocopilla (Chile) plants.

Luftfahrtforschung. Band 1, heft 1-4; Band 2, heft 1-4. Jan.-Aug., 1928. Munich, R. Oldenbourg, 1928. Illus., diagrs., 12 x 8 in., paper. Various prices, 3,40 r. m. to 6., r. m. each heft.

The Wissenschaftliche Gesellschaft für Luftfahrt has begun the publication of this new periodical which will appear at irregular intervals. It will bring together in convenient form reports on the research work done at the Deutsche Versuchsanstalt für Luftfahrt, the Aerodynamische Versuchsanstalt at Gottingen, the Aerodynamische Institut of the Aachen Technical High School, and other centers of research.

The first number reports investigations upon vibration in aerofoils and upon towing tests on floats. Number two describes extensive tests of an aluminum-copper-silicon alloy, lautal, to determine its value as a material for aircraft. Number three reports on the heat treatment of magnesium alloys, on mechanical tests of light-metal tubes, and on a new rope connection. The fourth number contains papers on radio and electrical problems.

The remaining numbers discuss equally important matters. The series will be important to every one interested in the design and construction of aircraft, and to metallurgists and mechanical engineers generally.

Manual of Surveying for Field and Office.

By Raymond E. Davis. 2d edition. N. Y., McGraw-Hill Book Co., 1928. 401 pp., plates, diagrs., tables, 7 x 4 in., fabrikoid. $3.00.

This manual is intended to teach the practise of surveying to students versed in its theory, and also as a text for short elementary courses such as are given to students of mechanical and electrical engineering. It aims to teach proper methods of using instruments, making surveys, computing, and mapping. The directions given are clear and detailed. The book is small enough to fit the pocket easily.

Mathematische Stromungslehre.

By Wilhelm Müller. Berlin, Julius Springer, 1928. 239 pp., 10 x 7 in., paper. 18.–r. m.

This treatise on the motion of fluids is based on the author's lectures, at the Hannover Technical High School, to students of mathematics, technical physics, and aviation. It occupies a middle ground between the purely systematic and the essentially technical treatment of the subject.

The first portion of the book develops mathematically the theory and the mathematical formulas. The second portion directs attention to practical calculations of the forces on rotating cylinders, the theory of aerofoils and propellers, and the flow in turbines.

Les Mesures de Temperatures Courantes.

By William Dériaz. Paris, Ch. Béranger, 1927. 148 pp., 7 x 5 in., paper. 13 fr.

Explains the principles of industrial thermometry, describes the various thermometers used and the scales employed, and discusses possible errors in the measurement of temperatures under industrial conditions, with the methods by which these errors may be eliminated or measured.

Mineralogy.

By Edward Henry Kraus and Walter Fred Hunt. 2d edition. N. Y., McGraw-Hill Book Co., 1928. 604 pp., illus., 9 x 6 in., cloth. $3.00.

An attractive textbook, distinguished by fine photographs of crystals and minerals, and of prominent mineralogists. The authors have aimed to cover the essentials of crystallography and descriptive and determinative mineralogy in one volume which will serve the needs of the average student.

The new edition is revised throughout. Many new illustrations have been added and there is a new chapter on crystal structure and X-ray analysis.

Practical Hydraulics; a Series of Rules and Tables.

By Thomas Box. 17th edition. Lond., E. & F. N. Spon, 1928. 112 pp., illus., tables, 8 x 5 in., cloth. 6s.

This new edition has been revised and reset, and additional tables added. The rules cover the ordinary hydraulic problems in practise, and the formulas are simple arithmetical ones.

PRACTICAL RADIO.

By James A. Moyer and John F. Wostrel. 3rd edition. N. Y., McGraw-Hill Book Co., 1928. 378 pp., illus., diagrs., 8 x 5 in., cloth. $2.50.

Improvement in radio apparatus during the last two years has made it necessary to revise this popular textbook. It explains the construction of radio receiving sets and the theory underlying them, discusses their selection, operation and testing, and gives directions for building a few popular types. Beginners will find this book a good introduction to the subject.

RATIONAL MECHANICS.

By Richard De Villamil. Lond., E. & F. N. Spon; N. Y., Spon & Chamberlain, 1928. 214 pp., 9 x 6 in., cloth. 10/6.

Colonel de Villamil discusses a number of fundamental difficulties in the theory of mechanics, as taught today. Many theories now accepted are irrational, in his opinion, and for these he offers substitutes. His book is directed to engineers, rather than mathematicians, and is intended to stimulate independent thinking upon basic problems.

THE SLIDE RULE.

By G. A. Gunn. Lond., E. & F. Spon, 1928. 40 pp., 7 x 4 in., cloth. 2s.

This little work explains briefly and practically the use of the ordinary slide rule for multiplying and dividing, and for obtaining squares and square roots. It also gives directions for working out cubes and cube roots, and for trigonometrical calculations with the System Rietz slide rule.

STANDARDS AND STANDARDIZATION.

By Norman F. Harriman. N. Y., McGraw-Hill Book Co., 1928. 265 pp., illus., 9 x 6 in., cloth. $3.00.

Considers such matters as the evolution of standards and their application in industry, the derivation of units, the purpose of standards, the advantage of standardization, methods of standardizing, and national standardizing bodies and laboratories. These and other topics are discussed in a broad manner, with particular reference to their importance in manufacturing.

TRANSFORMER CONSTRUCTION AND OPERATION.

By Emerson G. Reed. N. Y., McGraw-Hill Book Co., 1928. 227 pp., illus., diagrs., tables, 9 x 6 in., cloth. $3.00.

This book, based on lessons used in the classes of the Westinghouse Electric and Manufacturing Company, is intended primarily for practical electrical workers. Attention is directed to present practice in construction and operation, which are discussed thoroughly in detail. Mathematics is avoided, as is design.

UBER DIE FESTIGKEIT EINWANDIGER KEGELIGER KOLBEN.

By Herman Tellers. (Forschungsarbeiten auf dem gebiete des Ingenieurwesens, heft 305.) Ber., V. D. I. Verlag, 1928. 30 pp., diagrs., tables, 12 x 9 in., paper. 4,50 r. m.

A detailed theoretical and experimental study of the stresses in conical pistons, such as are used especially in marine and rolling-mill engines. The author develops a method by which the stress at any point may be determined, and gives a critical report on the methods used in the past.

DER WARME—UND KALTESCHUTZ IN DER INDUSTRIE.

By J. S. Cammerer. Berlin, Julius Springer, 1928. 276 pp., diagrs., tables, 9 x 6 in., cloth. 21,50 r. m.

This treatise on heat insulation is intended to meet the practical needs of refrigerating engineers. The author brings together the known scientific facts of importance and from them develops a simple method of calculation suitable for practical purposes. A large part of the data are presented in tables and diagrams.

Engineering Societies Employment Service

Under joint management of the national societies of Civil, Mining, Mechanical and Electrical Engineers cooperating with the Western Society of Engineers. The service is available only to their membership, and is maintained as a cooperative bureau by contributions from the societies and their individual members who are directly benefited.

Offices:—31 West 39th St., New York, N. Y.,—W. V. Brown, Manager.
1216 Engineering Bldg., 205 W. Wacker Drive, Chicago, Ill., A. K. Krauser, Manager.
57 Post St., San Francisco, Calif., N. D. Cook, Manager.

MEN AVAILABLE.—Brief announcements will be published without charge but will not be repeated except upon requests received after an interval of one month. Names and records will remain in the active files of the bureau for a period of three months and are renewable upon request. Notices for this Department should be addressed to ***EMPLOYMENT SERVICE, 31 WEST 39th Street, New York City,*** *and should be received prior to the 15th day of the month.*

OPPORTUNITIES.—A Bulletin of engineering positions available is published weekly and is available to members of the Societies concerned at a subscription of $3 per quarter, or $10 per annum, payable in advance. Positions not filled promptly as a result of publication in the Bulletin may be announced herein, as formerly.

VOLUNTARY CONTRIBUTIONS.—Members obtaining positions through the medium of this service are invited to cooperate with the Societies in the financing of the work by contributions made within thirty days after placement, on the basis of one and one-half per cent of the first year's salary: temporary positions (of one month or less) three per cent of total salary received. The income contributed by the members, together with the finances appropriated by the four societies named above will it is hoped, be sufficient not only to maintain, but to increase and extend the service.

REPLIES TO ANNOUNCEMENTS.—Replies to announcements published herein or in the Bulletin, should be addressed to the key number indicated in each case, with a two cent stamp attached for reforwarding, and forwarded to the Employment Service as above. Replies received by the bureau after the positions to which they refer have been filled will not be forwarded.

POSITIONS OPEN

ELECTRICAL-MECHANICAL ENGINEER with experience in manufacture of high-tension underground and overhead equipment; oil switch experience particularly desirable; good knowledge of modern shop practise and ability to coordinate designing and manufacturing essential. Salary $4800 a year. Apply by letter. Location, Middle west. X-537-C.

DISTRIBUTION ENGINEERS, 28-36, for work in Latin American countries. Must be thoroughly experienced in the design, construction and operation of overhead distribution systems. Must speak Spanish fluently. Single man preferred. Apply by letter. X-6027.

MECHANICAL ENGINEER, 20 to 30 years old, preferably one or two years graduate work. Testing, investigations and reports. Steam generating plant or public utility in Eastern city. Apply by letter. X-6259.

MEN AVAILABLE

ELECTRICAL ENGINEER, 43, married, graduate Purdue University. General Electric test, laboratory research on auto and train equipment, broad experience in a-c. and d-c. motor design. Six years in charge of a-c. motor design. Available at once. C-5065.

ELECTRICAL ENGINEER, 30, single. Technical University graduate, broad experience in design, construction, transmission, distribution and investigation work on cables. Desires connection with public utility or manufacturing concern. Available immediately. Location preferred, United States or Europe. C-5098.

TECHNICAL GRADUATE in electricity, also power plant design; experienced in meters, distribution wiring, application of light and power, water power and semi-Diesel, construction of small plant and all types of maintenance. Prefer design, construction or maintenance. At present in business, will go anywhere. B-9007.

APPRAISAL ENGINEER, EXPERT; graduate electrical engineer. Ten years' experience compiling detail cost analyses, construction estimates, inventories and valuations of plants and equipment owned by electric and gas public utilities for bankers reports, classified accounting systems, continuous physical property records, rate and capitalization cases. Formerly with New York State Public Service Commission. B-9636.

RAILWAY SIGNAL ENGINEER, graduate E. E., 27, single, good health. Five years' experience in railway signaling; three years in

Spain, speaks and writes German, Spanish and French; desires permanent position with large manufacturing or railway concern. Available on two weeks' notice. C-5056.

ELECTRICAL ENGINEER, 33, graduate, 10 years' utility experience, desires position as assistant executive or department head. Besides general experience, has had considerable distribution work in both power and traction companies. Now employed. Available reasonable notice. Location, United States, West preferred. C-5091.

ELECTRICAL ENGINEER, 25, single, graduate, B. S. degree; long enough out of college to have become pretty well seasoned, desires a position with an engineering organization, manufacturing or utility company that needs a young technical man who is earnest and ambitious to the extent of filling executive opening or work leading to such. Location, immaterial, East preferred. C-5063.

ELECTRICAL ENGINEER, married, 30, best of reverences. Seven years' distribution and operating experience, desires connection as distribution or plant engineer with operating company in south or southwest. C-4734.

ELECTRICAL ENGINEERING GRADUATE with four years' practical experience, available for technical work to be performed at home. Calculation and tracing a specialty. Location, New York City. C-3593.

ELECTRICAL ENGINEER, 24, married, B. S. 1928, desires opportunity in the electrical field, radio, research; New York or near by; salary secondary; speaks English, French and German. C-5084.

ELECTRICAL ENGINEER, having eight years' practical experience on transmission, distribution, testing and sales work is desirous of a connection with progressive concern. Willing to accept position in Europe. B-7412.

ELECTRICAL AND MECHANICAL ENGINEER, 42, married. Technical University graduate. Sixteen years of practical experience in the design, test and operation of a-c. and d-c. motors, generators; relays, contactors and control apparatus, switch board panels. Elevator construction, hoisting equipment and installations. Development and production work. Location, preferably East. B-5240.

ELECTRICAL ENGINEER, married, no family, Protestant; as executive and designer with thirteen years' experience on the design and erection of steam power plants; 13.2 kv., 66 kv. and 110 kv. Knowledge of Spanish. No preference as to location. B-9504.

ELECTRICAL DRAFTSMAN, 28, married. Graduate Electrical Engineer, desires position with industrial concern. Three and one-half years' electrical shop experience and four years as draftsman with a manufacturing company. Available immediately. Location, East. C-1310.

ELECTRICAL GRADUATE, 1926, 25, single, American parentage. Six months' experience in substation construction, outdoor and indoor types; five months in relay and control work; six months in substation operation and past eight months in load dispatching with public utility. Also experience in interior wiring and concrete work. Location desired, South or Middle Atlantic States, Eastern United States. C-2122.

GRADUATE ELECTRICAL ENGINEER, 24, single. Four years' electrical experience; two years design and construction of central and substations and one year electrolysis surveyor. For the past year engaged in the design and supervision of construction of large automatic railway power distribution system; this work nearing completion. Location, immaterial, foreign preferred. C-5151.

ELECTRICAL ENGINEER, German and I. C. S. graduate, 30, American citizen. Eight years' experience in relay work, automatic substations, metering and installation tests. Will go anywhere. Two weeks' notice necessary. C-5154.

ELECTRICAL ENGINEERING GRADUATE, 29, married. One and one-half years General Electrical Test, one and one-half years' design experience with large public utility holding company, desires position with operating company, electric railway, or manufacturing organization. Location, immaterial. C-5145.

LICENSED PROFESSIONAL ELECTRICAL ENGINEER, 37, married, 16 years' broad experience in electrical design, construction and operation of Power Stations, substations, lighting and power for industrial buildings; office and experience in appraisal work; desires a new connection with an engineering organization or public utility. B-5393.

DISTRIBUTION ENGINEER, Graduate Electrical Engineer, 1923. General Electric Test; thoroughly familiar with design, construction and operation of overhead distribution systems, 2300 to 13,200 volts; some experience with underground distribution. Capable of organizing and directing construction and maintenance work and system of records. Now employed, available on reasonable notice. C-5155.

GRADUATE ELECTRICAL ENGINEER, experienced on switching and associated problems. Design and layout of outdoor and indoor bus and breaker structures. Design, construction and installation switchboards; relaying experience. Will go anywhere on 30 days' notice. Utility or manufacturing connection preferred. Salary dependent on possibilities for advancement, \$200-\$250 per month. C-4519.

ELECTRICAL MECHANICAL ENGINEER, American, married, executive ability, with several years' experience design, development of signal and automatic control systems, for power and industrial plants, radio equipment, etc. Now employed but will consider suitable, permanent opening with large company offering opportunity. Prefer Eastern location. B-2395.

ELECTRICAL ENGINEER-DESIGNER, 30, single, three years college. Eight years' experience on substation and power station on design, layout and supervision of installation. Desires a position along engineering lines. C-5111.

ELECTRICAL-MECHANICAL ENGINEER, 31, married, American. Four years (pre-graduation) electrical maintenance, steel mills. One year General Electric Test; two and one-half years Design Draftsman, public utility; one-half year instructor, electrical subjects, shop practise; one year assistant to electrical engineer, large industrial, operating own hydroelectric generating plants. Desires responsible position with industrial or public utility. C-2902.

MEMBERSHIP—Applications, Elections, Transfers, Etc.

APPLICATIONS FOR TRANSFER

At its meeting held October 3, 1928, the Board of Examiners, recommended the following members for transfer to the grade of membership indicated. Any objection to these transfers should be filed at once with the National Secretary.

To Grade of Member

ADAMS, JOHN B., Switchgear Specialist, Allis-Chalmers Mfg. Co., New York, N. Y.
APPLEGATE, LINDSAY M., Electrical Engineer, City Engineers Dept., Seattle, Wash.
ARIAS, BERNARDO E., Supt. of Electrical and Telegraph Dept., National Railways of Mexico, Mexico, D. F.
ARNOLD, BENJAMIN H., Director, Engg. Service Dept., Victor X-Ray Corp., Chicago, Ill.
BANGRATZ, ERNEST G., Instructor in Elec. Engg., Mass. Inst. of Tech., Cambridge, Mass.
CROSS, HARRY, Equipment Engineer, Mexican Tel. & Tel. Co., Mexico, D. F.
DAWSON, EDWARD B., Section Engineer, Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.
DEARMIN, HARRY M., Supervising Draftsman (Designer), Pacific Gas & Elec. Co., San Francisco, Calif.
DOWNER, CHARLES B., Supervisor, Distribution Specifications, West Penn Power Co., Pittsburgh, Pa.
FLEMING, G. A., Design Engineer, Southern California Edison Co., Los Angeles, Calif.
GRAM, JOHN I., Asst. Meter Supervisor, Niagara Falls Operating Office, H. E. P. C. of Ontario, Ont., Canada.
HARMONY, CHARLES A., Division Supt., Puget Sound Pr. & Lt. Co., Bothell, Wash.
HESS, JOSEPH C., Shop Supt., Leeds & Northrup Co., Philadelphia, Pa.
HOFMANN, A. CL., Chief Engineer and Partner, G. Rohland & Co., Berlin, Germany.
MASON, ROGER, Asst. to Vice-President, Mackay Companies, New York, N. Y.
McKEE, ROSCOE C., Asst. to Distribution Engineer, West Penn Power Co., Pittsburgh, Pa.
MOORE, RAYMOND P., Mechanical Engineer, Buffalo General Elec. Co., Buffalo, N. Y.
RATH, EDWIN R., Manager, Electricial Division, Philip Carey Co., Cincinnati, Ohio.
ROBERTS, EUGENE A., Local Manager, Southwestern Public Service Co., Carlsbad, N. M.
SCHOLZ, WILLIAM P., Asst. Engr., Interborough Rapid Transit Co., New York, N. Y.
SLOAN, ROYAL D., Prof. of Elec. Engg., and Vice Dean of Engg., State College of Washington, Pullman, Wash.
SMITH, BURKE, Transmission Engineer, Illinois Bell Telephone Co., Chicago, Ill.
SPRAY, GEORGE C., Asst. Elec. Engr., West Penn Power Co., Pittsburgh, Pa.
St. CLAIR, WARD K., Field Engineer, Bell Telephone Laboratories, Philadelphia, Pa.
WELLS, ARCHIBALD R., Meter Engineer, Hydro Electric Power Commission, Toronto, Ont., Canada.
WILDER, LAURENCE R., Chairman, Shipbuilding Division, American Brown Boveri Elec. Corp., New York, N. Y.
WILLIAMS, FRED M., General Installation Engineer, Western Electric Co., New York, N. Y.
WILLIS, FREDERICK C., Electrical Apparatus Designer, Bell Telephone Laboratories, New York, N. Y.
WILSON, ALBERT E., Asst. Elec. Engr., Canadian & General Finance Co., Toronto, Ont., Canada.

APPLICATIONS FOR ELECTION

Applications have been received by the Secretary from the following candidates for election to membership in the Institute. Unless otherwise indicated, the applicant has applied for admission as an Associate. If the applicant has applied for direct admission to a higher grade than Associate, the grade follows immediately after the name. Any member objecting to the election of any of these candidates should so inform the Secretary before November 30, 1928.

Andree, C. A., University of Wisconsin, Madison, Wis.
Arbuckle, W. B., Wagner Electric Corp., Houston, Texas

Augustine, W. J., General Electric Co., Schenectady, N. Y.
Barbour, F. S., New York Telephone Co., New York, N. Y.
Batchelder, D. E., Westinghouse Elec. & Mfg. Co., Sharon, Pa.
Bidwell, C. H., Bell Telephone Laboratories, New York, N. Y.
Bird, D. H., Cline Electric Mfg. Co., Chicago, Ill.
Bliss, C. S., Bliss Electrical School, Takoma Park, D. C.
Boyd, D. L., (Member), The Hoover Co., North Canton, Ohio
Brown, J. G., Savannah Electric & Power Co., Savannah, Ga.
Bruhlman, G., American Brown Boveri Electric Corp., Camden, N. J.
Bruin, M. R., Southern Railway Co., Washington, D. C.
Bucher, P. J., Duquesne Light Co., Pittsburgh, Pa.
Campbell, W. M., Toledo Edison Co., Toledo, Ohio
Cardwell, L. H., Dallas Power & Light Co., Dallas, Texas
Conde, H. G., General Electric Co., New York, N. Y.
Cook, K. N., Rollway Bearing Co., Syracuse, N. Y.
Cooke, A. F., So. California Edison Co., Santa Barbara, Calif.
(Applicant for re-election.)
Crego, George William, Lake Superior District Power Co., Saxon, Wis.
Darrin, R. M., General Electric Co., Buffalo, N. Y.
Davis, C. L., (Member), John B. Brady, Washington, D. C.
Davis, F. E., Jr., Commonwealth Power Corp. of Michigan, Jackson, Mich.
Derry, H. W., Pennsylvania Power & Light Co., Allentown, Pa.
Dillingham, H. C., A. & M. College of Texas, College Station, Texas
Driscoll, C. C., Commonwealth Power Corp. of Michigan, Jackson, Mich.
Duetz, J. C., General Electric Co., Philadelphia, Pa.
Dunstan, G. H., Tulane Univ., New Orleans, La.
Ellenwood, W. E., Broadcast Station WKBQ, New York, N. Y.
Flagg, W. E., Electrical Contracting & Engineering, Wellesley and Boston, Mass.
Goldsmith, S., Union Gas & Electric Co., Cincinnati, Ohio
Hagemann, J. R., American Brown Boveri Electric Corp., Camden, N. J.
Harbison, H. W., Kansas City Power & Light Co., Kansas City, Mo.
Harris, F. T., United Eng. & Con. Co., Philadelphia, Pa.
Horne, W. H., Jr., Central Hudson Gas & Electric Corp., Newburgh, N. Y.
Howard, A., General Electric Co., Schenectady, N. Y.
Howe, H. S., General Electric Co., Schenectady, N. Y.
Howell, K. L., Penn-Ohio Power & Light Co., Salem, Ohio
Kean, A. J., Southwestern Bell Telephone Co., Dallas, Texas
Kelley, K. C., Westinghouse Elec. & Mfg. Co., Sharon, Pa.
Kelly, H. R., General Electric Co., Schenectady, N. Y.
Kuhn, O. G., 1350 Bushwick Ave., Brooklyn, N. Y.
Lail, G. G. (Member), General Electric Co., Pittsburgh, Pa.
Latta, M. G., Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.
Marshall, S. W., Jr., Texas Power & Light Co., Dallas, Texas
Martin, E. F., Illinois Bell Telephone Co., Chicago, Ill.
Mather, W. L., Lynn Gas & Electric Co., Lynn, Mass.
Mayer, C. F., So. New England Telephone Co., New Haven, Conn.
Mayer, C. H., Westinghouse Lamp Co., Bloomfield, N. J.
McIlvenny, J. E., Bessemer Limestone Co., Youngstown, Ohio
McKenzie, D. J., Toronto Hydro-Electric System, Toronto, 2, Ont., Can.
Meyer, F. R., So. New England Telephone Co., New Haven, Conn.
Norton, F. L. W., Westinghouse Elec. & Mfg. Co., Sharon, Pa.
Olsson, O. G., Westinghouse Elec. & Mfg. Co., Sharon, Pa.
Owen, R. R. (Member), General Electric Co., Pittsburgh, Pa.
Patten, I. A., Lynn Gas & Electric Co., Lynn, Mass.
Pinkerton, R. R. (Member), Sanitary Dist. of Chicago, Chicago, Ill.
Pokorny, E. J., New York Telephone Co., Mt. Vernon, N. Y.
Prichard, C. R. (Member), Lynn Gas & Elec. Co., Lynn, Mass.
Reagan, J. E., C. E. Mountford, New York, N. Y.
Redewill, A. C., General Electric Co., San Jose, Calif.
(Applicant for re-election.)
Roberts, J. M., Louisiana Polytechnic Institute, Ruston, La.
Ross, M., New York Edison Co., New York, N. Y.
Rupp, F. C., Staten Island Edison Co., Livingston, S. I., N. Y.
Shaughnessy, L. J., Bell Telephone Company of Pennsylvania, Sharon, Pa.
Soxman, G. M., Southwestern Bell Tel. Co., Dallas, Texas
(Applicant for re-election.)
Stephenson, W. B., Southwestern Bell Tel. Co., St. Louis, Mo.
Strain, J. R., Southern California Edison Co., Big Creek, Calif.
Stratton, J. A., Massachusetts Institute of Technology, Cambridge, Mass.
Sugioka, J. K., Brooklyn Edison Co., Brooklyn, N. Y.
Swafford, J. D., Kansas City Power & Light Co., Kansas City, Mo.
Thompson, W. C., Bureau of Power & Light, Los Angeles, Calif.
Tinling, H. B., Tinling & Powoll, Spokane, Wash.
Tudbury, J. L., Salem Electric Lighting Co., Salem, Mass.
Waltz, R. B., F. R. Jennings Co., Detroit, Mich.
Weber, A. N., Lynn Gas & Electric Co., Lynn, Mass.
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Novalux Electric Traffic Signals.—Bulletin GEA-566A, 24 pp. Describes G-E Novalux traffic signals. Problems of traffic regulation are discussed and the application of signals for regulation is illustrated. General Electric Company, Schenectady, N. Y.

Students' Kelvin Bridge.—Bulletin 434, 8 pp. Describes the students' Kelvin bridge, a convenient instrument for teaching the Kelvin bridge system for measuring low electrical resistances accurately. The Leeds & Northrup Company, 2901 Stenton Avenue, Philadelphia, Penn.

Battery Chargers.—Bulletin TC-24 describes Balkite charging equipment which is especially adapted for the charging of telephone batteries such as are used in connection with magneto switchboards, P. B. X. boards and small central office boards. The Fansteel Products Company, Inc., North Chicago, Ill.

Instruments.—Bulletin AE-160, describes types GSA, HTA and ISA portable a-c. ammeters, milli-ammeters, voltmeters, volt-ammeters, wattmeters, frequency meters, power factor meters and transformers. Bulletin AE-400 describes types TD and FD, 3½ in. and 4 in. panel type, d-c. ammeters, milli-ammeters, voltmeters, milli-voltmeters and volt-ammeters. The Roller-Smith Company, 12 Park Place, New York.

NOTES OF THE INDUSTRY

The Roller-Smith Company, 233 Broadway, New York, has announced the appointment of Wise & Braisted, General Motors Building, Detroit, as district sales agent in the state of Michigan, and Arthur H. Abbott, Inc., 88 Broad Street, Boston, as its agent for the New England territory.

Increased Orders for G. E. Company.—Orders received by the General Electric Company for the three months ended September 30 amounted to $90,328,666, compared with $77,420,263, for the corresponding quarter of 1927, an increase of 17 per cent, President Gerard Swope has announced. For the nine months ended September 30, orders received amounted to $260,686,463, compared with $233,076,091, for the first nine months of last year, an increase of 12 per cent

E. C. Brown Retires from Ohio Brass Company.—Connected with the public utility industry for many years, twenty-one of which he spent with the Ohio Brass Company, E. C. Brown is retiring from active duty and moving to California, which has been his plan for some time. Mr. Brown was on the sales force of the Ohio Brass Company in the Mississippi Valley until about two years ago, when he took over the supervision of the soutwest district. It is this position which he is resigning at the present time. He takes with him the best wishes of his host of friends in the O-B organization and in the industry generally.

New System for Fire Protection.—The American-LaFrance and Foamite Corporation, Utica, N. Y., has placed on the market a system of carbon dioxide protection against fire known as the Alfite System, which may be operated manually or automatically. The Alfite System employs an inert gas confined in a liquid state in metal cylinders and piped to nozzles located at the fire hazard. Here the gas is liberated in the room or space being protected. The system is especially applicable in the electrical field, because carbon dioxide is a non-conductor of electricity and will not damage electrical equipment.

Copperweld Steel Company Announces Appointments.—According to a recent announcement from the Copperweld Steel Company, of Glassport, Penn., manufacturers of electrical rod, wire and strand products which consist of a core of steel around which has been molten welded a heavy exterior of copper, Lowell S. Monroe, formerly advertising manager of the Electric Controller & Manufacturing Company, is now a member of the Copperweld engineering staff in charge of service data.

P. A. Terrell, formerly manager of the New Industries Division of the Mississippi Power Company, has assumed charge of central station and railroad sales for the Copperweld Steel Company, in the states of Tennessee, Mississippi, Alabama, Florida and Georgia.

I. G. E. Contracts with Russia for Electrical Apparatus.—The International General Electric Company and the Amtorg Trading Corporation of New York recently signed a contract covering the supply of electrical apparatus for export to the Union of Soviet Socialist Republics (Russia). The contract provides for the purchase on the part of the Amtorg Corporation of not less than $5,000,000 or more than $10,000,000 worth of apparatus and material during the first two years. A payment of 25 per cent is required before shipment of the materials and the balance is to be covered by trade acceptances falling due within a period of five years from date of shipment. Provision is made upon the satisfactory completion of the purchases during the first two years for the continuation of the contract for a further period of four years, involving purchases of not less than $4,000,000 annually. The contract and all acceptances bear the unconditional guarantee of the Russian State Bank.

Large Air-Blast Transformers for New York Edison Company.—Two air-blast transformers, greater in kilovolt-ampere capacity and larger physically than any others so far produced, have been completed at the Pittsfield works of the General Electric Company for the Waterside Station of the New York Edison Company, where they will operate in connection with a 40,000-kilowatt induction synchronous frequency set.

Each unit is rated air-blast, three-phase, 25 cycles, 18,500-kilovolt-amperes, and 11,800/3300//440 volts. From the outside, the transformers have the appearance of solid, square blocks of gray iron, and, as a matter of fact, iron makes up more than half of the total weight of 54 tons. From the floor to the top of the casing, they stand 13 feet high, and they occupy a floor space 6½ by 11 feet.

This floor space, while exceptionally large for an air-blast transformer, is comparatively small when judged by other standards. A transformer of similar rating, if oil-immersed for instance, would take up roughly twice as much floor space. Therein lies one of the chief advantages of air-blast transformers.